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(71)(72) Applicant and Inventor: GUARINI, Vittorio [IT/IT]; Corso Rosselli, 91 bis/16, I-10129 Torino (IT).

(74) Agents: MARCHITELLI, Mauro et al.; Jacobacci & Perani S.p.A., Corso Regio Parco, 27, I-10152 Torino (IT).

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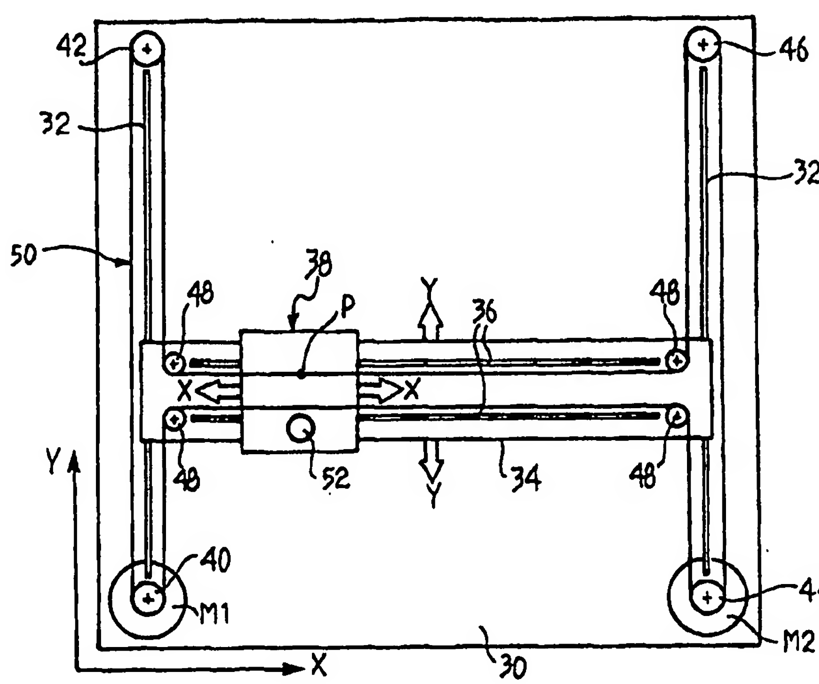
(54) Title: A TRANSMISSION DEVICE WITH TWO OR MORE AXES AND WITH STATIONARY MOTORS

(57) Abstract

A transmission device for moving an operator member along at least two axes, comprising drive means (M1, M2) in stationary positions cooperating with at least one flexible transmission member (50) which can bring about the movement of the operator member along at least two axes.



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A transmission device with two or more axes and with stationary motors

The present invention relates to a transmission device which can impart a movement along two or more axes to a generic operator member by means of motors which are in stationary positions, that is, which are not movable along the axes of movement of the device.

In conventional devices, for example, with male-and-female-screw or rack-and-pinion transmission mechanisms, in order to achieve a movement along two axes, it is necessary for at least one of the motors to be movable. This involves an increase in the power of the motors, a decrease in the possible acceleration and hence in speed, and a considerable overall increase in cycle times. Another disadvantage is that, in order to supply the motors and to make use of position and speed transducers, it is necessary to carry out cabling which must allow the motors to move.

The object of the present invention is to overcome the aforesaid disadvantages by the provision of a device with a reduced movable mass, with great agility of movement, with low-power motors, with considerable structural simplicity and with a production cost much lower than that of conventional systems.

According to the present invention, this object is

achieved by a device having the characteristics forming the subjects of the claims.

The device according to the invention may be used in very many fields such as, for example, in handling devices, in machine tools, in measurement machines, in plotters and in printers and, in general wherever there is a need to move a generic operator member along at least two axes. For the purposes of a correct interpretation of the scope of protection of the present invention, it should be pointed out that the term "axes" of the transmission device is intended to mean the degrees of freedom of the operator member and this term therefore also includes rotary movements as well as movements along linear axes. For example, a transmission device will consequently be said to have two axes if it can bring about, individually, a rotary movement of an operator member about an axis and a translational movement of the same member along a linear axis.

Moreover, it should be pointed out that the device according to the present invention is not limited to any specific embodiment of the operator member which may be constituted, at any particular time, according to need, by a tool-holder unit, a movable table, a laser focusing head, a measurement feeler, a printing head, etc..

According to the invention, a transmission device with two axes may be produced by means of two stationary motors cooperating with the same flexible transmission member which extends along a path with variable geometry. Alternatively, a device with two axes can be produced with a single motor and two brakes which selectively

prevent the movement of the operator member along one or other of the two axes.

Devices with three or four axes can be produced by the addition of a further flexible transmission member and a motor for each axis. Configurations of devices with three axes which use two motors and two brakes, or configurations with four axes which use two motors and three brakes are also possible.

According to requirements, the flexible transmission member may be disposed on a generally H-shaped path or a generally cross-shaped path. In both cases, the geometry of the device changes according to the position of the operator member.

The present invention will now be described in detail with reference to the appended drawings, provided purely by way of non-limiting example, in which:

Figure 1 is a schematic plan view of a first embodiment of the device according to the invention,

Figure 2 is a simplified diagram which shows the operating principle of the device of Figure 1,

Figure 3 is a vectorial representation of the device of Figures 1 and 2,

Figure 4 is a variant of the device of Figure 1,

Figure 5 is a schematic, perspective view showing a possible configuration for a device with four axes,

Figures 6 and 7 are schematic views relating to the parts indicated by the arrows VI and VII in Figure 5,

Figure 8 shows a variant of the diagram of Figure 6,

Figure 9 is a schematic, perspective view showing a male-and-female screw system for transforming a rotary axis into a linear axis,

Figure 10 is a schematic, perspective view showing a mechanism usable in combination with the device of Figure 5 to produce a vertical linear axis and a rotary axis,

Figures 11 and 12 are schematic views showing an alternative system for achieving a linear vertical axis or a rotary axis,

Figure 13 is a schematic view showing, by way of example, a device with three axes and with only two motors,

Figure 14 is a simplified diagram of the device of Figure 13,

Figure 15 is a diagram showing the possibility of producing a device with four axes and with two motors,

Figure 16 is a table listing the possible movements of the device of Figure 15,

Figures 17-19 are schematic views showing the possibility of moving several movable elements in the same working area,

Figure 20 is a schematic view of a second embodiment of the device according to the invention,

Figure 21 is a simplified diagram of the device of Figure 20,

Figures 22 and 23 show two variants of the device of Figure 20,

Figure 24 shows a possible embodiment of a device with four axes and with four motors,

Figures 25 and 26 are schematic views showing the parts indicated by the arrows XXV and XXVI in Figure 24,

Figure 27 shows a mechanism usable in combination with the device of Figure 24 to obtain a vertical linear axis and a rotary axis,

Figures 28 and 29 are schematic, perspective views showing an alternative system for obtaining a linear vertical axis and a rotary axis,

Figures 30 and 31 show a device with three axes and with two motors,

Figures 32-34 show devices with several elements movable in the same working area, and

Figure 35 shows a further variant of the device according to the invention suitable, in particular, for moving movable tables.

Figure 1 shows a transmission device comprising a stationary base 30 carrying a pair of guides 32 along which a slide 34 is slidable. The slide 34 carries a pair of guides 36 which extend in the direction of an X axis, and along which a carriage 38 is slidable.

The base 30 carries four return members 40, 42, 44, and 46 constituted, for example, by pulleys with stationary axes of rotation. The axes of rotation of the pulleys 40, 42, 44, 46 and 48 are perpendicular to the plane X-Y of Figure 1. The slide 34 carries a further four return members 48 also preferably constituted by pulleys which are in fixed positions on the slide 34; their axes of rotation cannot therefore move towards one another and are constrained to move solely in the direction of the X axis along which the slide 34 is movable.

A flexible transmission member 50 is wound around the pulleys 40, 42, 44, 46 and 48 in the configuration shown in Figure 2. The transmission member 50 may be constituted by a smooth or toothed belt, by a chain, by a cable, or by any other element. The return members are intended to be suitable for cooperating with the transmission member selected. Smooth or toothed pulleys will consequently be used if the transmission member 50 is constituted by a belt, or toothed wheels if the transmission member 50 is constituted by a chain. The transmission member 50 should be substantially inextensible, in the sense that it should not give rise to significant deformations within the range of forces which arise during normal operation. Normal, smooth or toothed, reinforced belts coated with elastomeric material which are normally available commercially are

perfectly suitable for use in the device according to the invention.

As can be seen in particular in Figure 2, the flexible transmission member 50 is arranged along a path with a generally H-shaped configuration comprising two passes 50a of fixed length extending in the direction of a Y axis, two passes 50b of fixed length extending in the direction of the X axis and four passes 50c and 50d of variable length extending in the direction of the Y axis. The carriage 38 carried by the slide 34 is fixed to one of the two passes 50b at the point indicated P.

An operator member carried by the carriage 38 is schematically indicated 52 in Figure 1. According to circumstances, the operator member may be fixed relative to the carriage 38, may be movable along an axis perpendicular to the plane X-Y, may be capable of rotary movement, or may be capable of both a translational movement and a rotary movement relative to the carriage 38. If the operator member 52 is fixed relative to the carriage 38, the device will have two axes. If the operator member is also capable of a rotary movement or a translational movement relative to the carriage 38, the device will have three axes and if, on the other hand, the operator member 52 is capable of both a translational movement and a rotary movement relative to the carriage 38, the device will have four axes.

As stated above, the operator member may take many forms according to the type of machine in which the transmission device according to the present invention is incorporated. The present invention is not intended to

be limited to any particular type of operator member.

In the embodiment shown in Figures 1 and 2, the return members indicated 40 and 44 are associated with respective motors M1 and M2. The rest of the return members 42, 46 and 48 do not have motors and are therefore in the form of pulleys or gears idle on their own axes of rotation. The motors M1 and M2 are controlled numerically by a conventional controller and have rates of rotation which are variable within a predetermined range. The motors M1 and M2 can thus impart various linear velocities of advance to the respective passes 50a and 50d of the flexible transmission member 50 by means of the respective pulleys 40 and 44. The motors M1 and M2 can also be braked in order to impart a zero velocity to the respective passes of the transmission member 50.

In order to illustrate the operation of the device according to the invention, reference will be made to the diagram of Figure 2, in which the four return members 48 are intended to be movable solely along the Y axis and relative movement between them is not permitted, whereas the point P of the flexible transmission member 50 is fixed to the carriage 38 and is constrained to move solely along the X axis relative to the return members 48. Naturally, the overall movement of the point P in the plane X-Y results from the combined movements of the return members 48 in the direction of the Y axis and of the point P relative to the return members 48. The diagram of Figure 2 shows a two-dimensional cartesian system of movement.

The following definitions are given: [1]

ω_1: angular velocity of the pulley driven by the motor M1 in the sense indicated in Figure 2;

ω_2: angular velocity of the pulley driven by the motor M2 in the sense indicated in Figure 2;

r: radius of the pulleys keyed to the motors M1 and M2;

V: velocity vector of the point P;

V_x: component of V along the X axis;

V_y: component of V along the Y axis;

V_1: velocity vector of the point P due solely to the contribution of ω_1;

V_2: velocity vector of the point P due solely to the contribution of ω_2;

V_{P1}; peripheral linear velocity of the pulley of the motor M1 owing to ω_1;

V_{P2}: peripheral linear velocity of the pulley of the motor M2 owing to ω_2.

The following relationships exist between ω_1,ω_2, V_{P1} and V_{P2}:

$$V_{P1} = \omega_1 . r \qquad [2]$$
$$V_{P2} = \omega_2 . r \qquad [3]$$

The velocity V as a function of the individual angular velocities ω_1 and ω_2 will be determined with the use of the principle of the superimposition of the effects, by the adding together of the contributions brought about separately by ω_1 and by ω_2. These contributions have been called V_1 and V_2.

<u>Calculation of the contribution V_1 brought about by ω_1 where $\omega_2 = 0$</u>

In these conditions, if ω_1 has the clockwise sense of Figure 2, the point P will be moved in the positive direction of a straight line X' rotated through -45° relative to the X axis, passing through the origin and oriented as in Figure 3. The absolute value of V_1 is as follows:

$$V_1 = \frac{\sqrt{2}}{2} \cdot V_{P1} \qquad [4]$$

<u>Calculation of the contribution V_2 brought about by ω_2, where $\omega_1 = 0$</u>

In these conditions, if ω_2 has the clockwise sense of Figure 2, the point P will move in the positive direction of a straight line Y' rotated through 45° relative to the X axis, passing through the origin and oriented as in Figure 3. The absolute value of V_2 is as follows:

$$V_2 = \frac{\sqrt{2}}{2} \cdot V_{P2} \qquad [5]$$

The axes X' and Y' obtained by rotation of the principal axes X and Y through -45° can be considered as the axes along which the point P moves owing to the angular velocities ω_1 and ω_2, or to the peripheral velocities V_{P1} and V_{P2}. In order to change from one system of coordinates to another, it suffices to apply a rotation transformation. The velocity vector V in the system of coordinates X-Y has components (V_X, V_Y) whereas in X'-Y' it has components (V_1, V_2).

The equations for transforming coordinates between X, X'

and Y, Y' are:

$$\begin{cases} x' = x\cdot\cos(-45°) + y\cdot\sin(-45°) \\ y' = y\cdot\cos(-45°) - x\cdot\sin(-45°) \end{cases} \Rightarrow \begin{cases} V_1 = V_x\cos(45°) - V_y\sin(45°) \\ V_2 = V_y\cos(45°) + V_x\sin(45°) \end{cases} \Rightarrow$$

$$\Rightarrow \begin{cases} V_1 = \dfrac{\sqrt{2}}{2}(V_x - V_y) \\ V_2 = \dfrac{\sqrt{2}}{2}(V_x + V_y) \end{cases} \qquad [6]$$

From formulae [4], [5] and [6]:

$$\begin{cases} V_{P1} = (V_x - V_y) \\ V_{P2} = (V_x + V_y) \end{cases} \qquad [7]$$

$$\begin{cases} V_x = \tfrac{1}{2}(V_{P1} + V_{P2}) \\ V_y = \tfrac{1}{2}(V_{P2} - V_{P1}) \end{cases} \qquad [8]$$

Or, taking account of formulae [2] and [3]:

$$\begin{cases} \omega_1 = \dfrac{1}{r}(V_X - V_Y) \\ \omega_2 = \dfrac{1}{r}(V_X + V_Y) \end{cases} \qquad [9]$$

$$\begin{cases} V_x = \dfrac{r}{2}(\omega_1 + \omega_2) \\ V_y = \dfrac{r}{2}(\omega_2 - \omega_1) \end{cases} \qquad [10]$$

The equations given above do not change if the position of the motor M1 is exchanged with that of the pulley 42 or if the position of the motor M2 is exchanged with that of the pulley 46 or both, the same senses of rotation of the motors being maintained.

It can be understood from formula [10] that the point P can be moved in any direction in the plane X-Y by suitable control of the angular velocities ω_1 and ω_2 of the motors M1 and M2. In this embodiment, the movements along the two axes X and Y are independent of one another

in the sense that it is possible to move the point P simultaneously along the X axis and along the Y axis.

Figure 4 shows a variant of the device of Figure 1. Elements corresponding to those described above are indicated by the same reference numerals. In comparison with the previous version, the variant of Figure 4 comprises only one motor M1, associated, for example, with the pulley 40. The device of Figure 4 also comprises a first brake 54 and a second brake 56. Both of the brakes can be activated and de-activated in dependence on commands received from the control unit of the machine. The first brake 54 is intended to lock the movement of the slide 34 relative to the base 30, and the second brake 56 is intended to lock the movement of the carriage 38 relative to the slide 34.

If the motor M1 is rotated and the brake 56 is kept locked, the operator member 52 is moved along the Y axis. If, on the other hand, the brake 54 is kept locked and the brake 56 is released, the operator member 52 is moved along the X axis. In this embodiment, the two axes of the device are therefore not independent. In comparison to the solution with two axes and with two motors, there is an advantage of the saving of one motor with its control system, but the ability to move the operator member along axes at any inclination to the axes X-Y is lost.

Following the description of the structure and the operation of transmission devices with two axes, some systems for increasing the number of axes of the device according to the invention will be described below.

A first of these systems is based on the principle of the addition of a further flexible transmission member with its own motor for each further axis to be added to the first two. An embodiment of this solution is shown in Figures 5-8.

Figure 5 shows schematically the arrangement of the flexible transmission members for a device with four axes. The first transmission member 50 is arranged in the same configuration as described above with reference to Figures 1 and 2 and cooperates with two motors M1 and M2. The transmission member 50 cooperates with the return members 48 carried by the slide 34 which is not shown in Figure 5. A point P of the transmission member 50 is fixed to the carriage 38 shown in broken outline. The device of Figure 5 comprises second and third flexible transmission members, indicated 58 and 60, which cooperate with respective motors M3 and M4 and with respective idle return pulleys 62 and 64 with stationary axes. The transmission members 58 and 60 also cooperate with return pulleys 66 and 68 carried by the slide 34 and with respective pulleys P3 and P4, the rotation axles of which are carried by the carriage 38. Figure 5 also shows auxiliary pulleys 74 and 76 which are carried by the carriage 38 and have the sole purpose of ensuring purely rolling engagement between the transmission members 58 and 60 and the respective pulleys P3 and P4.

Figures 6 and 7 show schematically the arrangement of the second and third transmission members of the device of Figure 5.

With reference to Figure 6, the pulley P3 is carried by

the carriage 38 which is moved in the plane X-Y by the first transmission member 50 under the control of the motors M1 and M2. The pulley P3, however, can rotate about its own axis both as a result of the movement imparted to it by the second transmission member 58, by means of the motor M3, and as a result of the movement of the carriage 38 in the plane X-Y. These effects are evaluated separately and then added together by the principle of the superimposition of the effects.

In addition to the previous definition [1], the following are also defined: [11]

ω_3: angular velocity of the pulley driven by the motor M3, in the sense indicated in Figure 6;

ω_{P3} angular velocity of the pulley P3 in the sense indicated in Figure 6;

V_{P3}: peripheral linear velocity of the pulley of the motor M3 owing to ω_3;

V_{PP3}: overall peripheral linear velocity of the pulley P3;

V'_{PP3}: peripheral linear velocity of the pulley P3 owing solely to V;

V''_{PP3}: peripheral linear velocity of the pulley P3 owing solely to ω_3.

With reference to the diagram of Figure 5:

$$\begin{cases} V'_{PP3} = V_y - V_x \\ V''_{PP3} = V_{P3} \end{cases} \qquad [12]$$

Since $V_{PP3} = V'_{PP3} = V''_{PP3}$, the following is *obtained from* formulae [7] and [12]:

$$\begin{cases} V_{P3} = V_{P1} + V_{PP3} \\ V_{PP3} = -V_{P1} + V_{P3} \end{cases} \qquad [13]$$

It can be seen from formula [13] that the kinematic equations of the third axis depend upon the peripheral velocity brought about by the motor M1.

With reference to Figure 7, the following are defined with regard to the fourth axis relating to the transmission member 60: [17]

ω_4: angular velocity of the pulley driven by the motor M4 in the sense indicated in Figure 7;

ω_{P4}: angular velocity of the pulley P4 in the sense indicated in Figure 7;

V_{P4}: peripheral linear velocity of the pulley of the motor M4 owing to ω_4;

V_{PP4}: overall peripheral linear velocity of the pulley P4;

V'_{PP4}: peripheral linear velocity of the pulley P4 owing solely to V;

V''_{PP4}: peripheral linear velocity of the pulley P4 owing solely to ω_4.

With reference to the diagram of Figure 7:

$$\begin{cases} V'_{PP4} = -V_y - V_x \\ V''_{PP4} = V_{P4} \end{cases} \qquad [18]$$

Since $V_{PP4} = V'_{PP4} + V''_{PP4}$, the following is obtained from formulae [7] and [18]:

$$\begin{cases} V_{P4} = -V_{P2} + V_{PP4} \\ V_{PP4} = V_{P2} + V_{P4} \end{cases} \qquad [19]$$

It will be noted that the equations [19] refer to the peripheral velocity of the motor M2, naturally in addition to the pulley P4.

It can also be shown that if the motor M4 were positioned in the same position as the motor M3 or in the same position as the motor M1, the equations [13] are obtained for the fourth axis and if the motor M4 is positioned in the same position as M2 the equations [19] are again obtained.

As well as being arranged according to the diagram of Figures 6 and 7, the further transmission members 58 and 60 could also be arranged according to the diagram of Figure 8 in which the pulley P3 is inverted in comparison with the diagrams described above. With this arrangement, the rotation of the pulley P3 (or P4) is reversed in comparison with that of the diagrams examined above.

The rotations ω_3 and ω_4 of the pulleys P3 and P4 enable two rotary axes to be obtained in addition to the two linear axes X and Y due to the first transmission member 50. One of the two rotary axes (for example, the axis relating to the pulley P4) can easily be transformed into a vertical linear axis Z with the use, for example, of a male and female screw device of the type shown schematically in Figure 9. In this drawing, the screw, which can move in the direction Z, is indicated 78 and the pulley P4 constitutes the female threaded element, the rotation ω_{P4} of which brings about the vertical

movement of the screw 78.

If the radius of the pulley P4 is indicated r and the pitch of the screw 1 is indicated H:

$$\omega_{P4} = \frac{V_{PP4}}{r} \qquad [14]$$

$$V_Z = \omega_{P4} \cdot H \qquad [15]$$

From formulae [14], [15] and [19]:

$$\begin{cases} V_{P4} = -V_{P2} + \dfrac{r}{H} \cdot V_Z \\ V_z = \dfrac{V_{P4} + V_{P2}}{r} \cdot H \end{cases} \qquad [16]$$

Figure 10 shows a device which, if associated with the second and third transmission members 58 and 60, enables a linear axis Z and a rotary axis to be obtained. As already stated above, the carriage 38 (indicated schematically in broken outline in Figure 10) is movable in the plane X-Y under the control of the motors M1 and M2. The pulleys P3 and P4 are free to rotate about their respective rotation axes relative to the carriage 38 but are restrained on the structure of the carriage for movements along the axes X, Y and Z. The pulley P4 acts as a female threaded member cooperating with the screw 78 which is movable along the vertical axis Z. The ends of the screw 78 are supported for rotating freely by a pair of plates 80 movable in the direction of the Z axis together with the screw 78. The plates 80 carry, by means of a pair of bearings 82, a rotary shaft 84 which is fixed for rotation with the pulley P3 but is free to slide in the direction of the vertical Z axis relative to the pulley P3. The rotary shaft 84 carries the operator member 52 which is shown schematically as a disc.

With the device shown in Figure 10, it is possible to achieve movements of the operator member 52 along the vertical axis Z by the rotation of the pulley P4 as well as rotary movements R of the member 52 by means of the rotation of the pulley P3. Moreover, the operator member 52 is movable in the plane X-Y together with the carriage 38. A device with four independent axes is thus obtained.

Figures 11 and 12 show an alternative system for achieving a vertical axis and a rotary axis without making use of the male and female screw mechanism. Figure 11 shows the arrangement of the second transmission member 58. The transmission member 58 again cooperates with four stationary pulleys 62 one of which is driven by the motor M3. Four pulleys 66 with vertical axes are again provided and are constrained to move solely in the directions X-Y. Unlike the device of Figure 5, in the version of Figure 11, the transmission member 58 cooperates with a pair of pulleys 86 rotatable in a plane parallel to the plane X-Z and movable in the direction of the X axis relative to the pulleys 66. The transmission member 58 has anchorage points 88 for its connection to a body movable in the direction of the Z axis. With the diagram of Figure 11, the rotation of one of the pulleys 62 brought about by the motor M3 of the Z axis will move the anchorage points 88 in a direction parallel to the Z axis.

Figure 12 shows an arrangement which enables a rotary axis to be obtained, for example, with the third transmission member 60. The transmission member 60 cooperates, as in the arrangement shown in Figure 5, with

stationary pulleys 64, one of which is driven by the motor M4, and with pulleys 68 movable in the direction of the Y axis. The transmission member 60 also cooperates with a pair of pulleys 90 mounted for rotating in a plane parallel to the plane X-Z and constrained to move in the direction of the X axis relative to the pulleys 68. A body (not shown) constrained to move in the direction of the Z axis carries a pulley 92 rotatable in a plane X-Z, a pair of pulleys 94 rotating in a plane parallel to the plane Y-Z and a pulley 96 rotatable in a plane parallel to the plane X-Y. With this arrangement, the rotation of one of the pulleys 64 brought about by the motor M4 of the rotary axis achieves a rotation of the pulley 96 connected to an operator member, not shown.

The diagrams of Figures 11 and 12 are intended to be integrated with one another in order to produce a system with four independent axes with four motors, according to the arrangement described with reference to Figure 5.

The operating principle upon which the present invention is based also enables three axes to be controlled with only two motors, according to the basic diagram shown in Figures 13 and 14. Figure 13 corresponds essentially to the diagram of Figure 1, with the difference that, instead of being fixed to the carriage 38, the transmission member 50 cooperates with a pulley 98 carried by the carriage 38 for rotating in a plane parallel to the plane X-Y. Two auxiliary pulleys 100 have the sole purpose of ensuring a purely rolling engagement between the transmission member 50 and the pulley 98. Moreover, the device of Figure 13 also comprises a first brake 102 and a second brake 104 which

can be activated in dependence on commands received from the control unit of the machine. When the first brake 102 is activated, it locks the carriage 38 relative to the slide 34, whereas when the second brake 104 is activated, it locks the pulley 98 relative to the carriage 38.

When the brake 104 is locked and the brake 102 is released, the device behaves exactly as that of Figure 1 and the carriage 38 can be moved in any direction in the plane X-Y. Conversely, when the brake 102 is activated and the brake 104 is released, both the rotation ω_{P3} and the movement along the Y axis are possible. With the brake 104 activated, the formulae [7], [8], [9] and [10] are also valid for the diagram of Figure 13. If the movement along the X axis is locked, it can be seen from Figure 14 that the velocity V_X can be replaced by the velocity V_{PP3} whilst the velocity V_Y remains unchanged so that the equations [7] and [8] are transformed as follows:

$$\begin{cases} V_{P1} = (V_{PP3} - V_y) \\ V_{P2} = (V_{PP3} - V_y) \end{cases} \qquad [20]$$

$$\begin{cases} V_{PP3} = \frac{1}{2}(V_{P1} + V_{P2}) \\ V_y = \frac{1}{2}(V_{P2} + V_{P1}) \end{cases} \qquad [21]$$

The rotary axis P3 can easily be transformed into a vertical axis as described above and as expressed by equations [14] and [15].

A similar solution of a device with three axes with only two motors can be achieved by the provision of a single flexible transmission member in the configuration shown in Figure 11 and the provision of two motors associated

with two different stationary pulleys and two brakes for alternatively locking the movement along the X axis or the movement along the Z axis.

Again with reference to Figure 11, with the provision, on the other hand, of a single motor associated with one of the pulleys 62 and three independent brakes, one operating on each axis, if two of the three brakes are kept engaged and the third is released, the rotation of the motor imparts a movement to the axis associated with the released brake, thus forming a system with three axes and only one motor.

An example of a transmission device with four axes with only two motors with the use of a single flexible transmission member will now be given with reference to Figure 15. The transmission member is arranged in the same configuration as shown in Figure 12 and, for convenience, the same reference numerals have been used in Figure 15 as in Figure 12. However, it should be pointed out that the diagram of Figure 12 shows the third transmission member within a device which comprises a further two, whereas in the case of Figure 15, there is only one transmission member. In the device of Figure 15, there are two motors M1 and M2, associated with two pulleys 64 with stationary axes. The device also comprises three brakes which can lock the movement along the X axis, the movement along the Z axis and the rotary movement of the pulley 96. The motors M1 and M2 are associated with the velocity and/or position transducers E1 and E2. Two drive devices indicated DRIVE 1 and DRIVE 2 control the rates of rotation of the motors M1 and M2 by means of the feedback signals produced by the

transducers E1 and E2 and by means of references V_{P1} and V_{P2}.

Each linear axis has a linear position transducer constituted, for example, by an optical rule, indicated rule X, rule Y or rule Z, and the rotary axis has an angular transducer indicated Enc.R. All of these position transducers provide feedback for a numerical control unit, indicated CONTROL, for four axes, which generates control signals which are sent to the drive devices DRIVE 1 and DRIVE 2 via adders V_{P1} and V_{P2}. The control unit also controls individually the operation of the three brakes of the X, Z and rotary axes, indicated brake X, brake Z and brake R.

The summary table of Figure 16 shows the relationship existing between various operative parameters of the device, according to the engaged or disengaged states of the brakes. In this table, the peripheral velocities of the pulleys of the motors M1 and M2 (which correspond to the references DRIVE 1 and DRIVE 2) are indicated V_{P1} and V_{P2}, the velocities on the axes X, Y and Z and the rotary axis are indicated V_x, V_y, V_z and V_r, respectively. The table specifies, for example, that if the axes X and Y are to be operated, it is necessary to disengage the brake X and to engage the brakes Z and R and that $V_{P1} = V_x - V_y$ and $V_{P2} = V_x + V_y$, and $V_z = V_r = 0$.

A system of this type is particularly cheap owing to the use of only two motors and drives instead of four. Moreover the mechanisms are inexpensive and have a high degree of precision owing to the presence of position transducers keyed directly on the axes. This solution

also enables the numerical control unit to regard the mechanical system as if it were a pure cartesian system with an independent motor for each axis, which considerably simplifies the formulation of the handling software.

Figures 17–19 show schematically the use of the system according to the invention for moving a plurality of operator members in the same area. In the version of Figure 17, two slides 34 movable along the same guides 36 are used. Each slide 34 carries a respective carriage 38. In the diagram of Figure 17, each slide 34 and each carriage 38 are associated with a respective flexible transmission member 50 driven by two motors. Altogether, two transmission members and four motors are therefore required.

In the version of Figure 18, two carriages 38 movable along the same guides 36 of the slide 34 are provided. In this case, the pair of motors M1 and M2 control the movement of one of the two carriages 38 in the plane X–Y. The motor M3 controls the movement of the second carriage 38 along the slide 34 by means of a further transmission member 50.

Finally, the two diagrams of Figures 17 and 18 can be combined to achieve four pairs of axes X–Y which are independent in pairs, as shown in Figure 19. For this arrangement, six motors and four flexible transmission members are required.

The operating principle upon which the present invention is based can be used to provide devices with various

geometrical shapes. In the embodiments described above, the device is generally H-shaped and occupies a generally quadrangular area in space. The structure and the operation of a different embodiment of the transmission device according to the invention, which may have some advantages in comparison with the device described above for certain types of application, will be described below.

Figures 20 and 21 show a transmission device with two independent axes comprising a stationary base 130 having guides 132 extending along the X axis. A slide 134 is slidable in the direction of the X axis on the guides 132 and carries an elongate carriage 138 which is constrained to move in the direction of the Y axis relative to the slide 134 by means of guides 136.

The stationary base 130 carries a pair of pulleys or similar return members 140, 142, associated with respective motors M1 and M2. The slide 134 carries four pulleys 148, rotatable in a plane parallel to the plane X-Y and having axes in stationary positions relative to the slide 134. The carriage 138 carries a pulley 149 which has a stationary axis relative to the carriage and is rotatable in a plane parallel to the plane X-Y.

As can be seen more clearly in Figure 21, the device comprises a transmission member 150 which is wound around pulleys 140, 142, 148 and 149 so as to form four passes parallel to the axis X and indicated 150a, 150b and four passes parallel to the axis Y and indicated 150c and 150d. The lengths of the passes 150a and 150b vary in

dependence on the movement of the slide 134 along the X axis and the lengths of the passes 150c and 150d vary as a result of the movement of the carriage 138 along the Y axis. In summary, it can consequently be said that the flexible transmission member 150 extends along a generally cross-shaped path with a variable configuration. The two different geometrical arrangements of the device according to the invention are referred to in short as the "variable H" device and the "variable cross" device. The points indicated P of the flexible transmission member 150 are anchored to the carriage 138 which carries an operator member, shown only schematically in the drawings and indicated 152.

The following definitions are given with reference to the diagram of Figure 21: [22]

ω_1;	angular velocity of the pulley driven by the motor M1 in the sense indicated in Figure 21;
ω_2:	angular velocity of the pulley driven by the motor M2 in the sense indicated by Figure 21;
r:	radius of the pulleys keyed to the motors M1 and M2;
V:	velocity vector of the point P;
V_X:	component of V along the X axis;
V_Y:	component of V along the Y axis;
V_1:	velocity vector of the point P due solely to the contribution of ω_1;
V_2:	velocity vector of the point P due solely to the contribution of ω_2;
V_{P1}:	peripheral linear velocity of the pulley of the motor M1 owing to ω_1;
V_{P2}:	peripheral linear velocity of the pulley of

the motor M1 owing to ω_2.

With these definitions which, moreover, are identical to those given above with reference to the "variable H" device, the same results as seen above and summarised in the following kinematic equations are achieved:

$$\begin{cases} V_{P1} = (V_x - V_y) \\ V_{P2} = (V_x + V_y) \end{cases} \qquad [23]$$

$$\begin{cases} V_x = \frac{1}{2}(V_{P1} + V_{P2}) \\ V_y = \frac{1}{2}(V_{P2} - V_{P1}) \end{cases} \qquad [24]$$

or:

$$\begin{cases} \omega_1 = \frac{1}{r}(V_X - V_Y) \\ \omega_2 = \frac{1}{r}(V_X + V_Y) \end{cases} \qquad [25]$$

$$\begin{cases} V_x = \frac{r}{2}(\omega_1 + \omega_2) \\ V_y = \frac{r}{2}(\omega_2 - \omega_1) \end{cases} \qquad [26]$$

The "variable cross" system has the following advantages in comparison with the "variable H" system:

a) its belt or chain length is shorter, on average, by one third;
b) it has greater bending strength during the transmission of the movement by reason of point a) above;
c) it has one pulley less which achieves greater efficiency in the transmission of the movement;
d) it is easier to produce;
e) it is cheaper; and
f) it takes up less space on the base which is generally valuable since it is intended to house

other machinery.

The disadvantages, on the other hand, are as follows:

a) the "variable cross" system has less static strength than the "variable H" system owing to the eccentricity of the useful load disposed at one end of the carriage 138 of Figure 20 relative to the line joining M1-M2; the "variable H" system is therefore more suitable where greater rigidity or precision of positioning are required; and

b) the "variable cross" system takes up twice as much air space as the other system, although this space is generally not used for other purposes.

The selection of one system rather than the other will therefore be made on the basis of the considerations expressed above.

Figure 22 illustrates the possibility of producing a device with two non-independent axes with the use of one motor M1 and two brakes 154 and 156. The brake 154 locks the movement of the slide 134 relative to the base 130 and the brake 156 locks the movement of the carriage 138 relative to the slide 134. If the brake 154 is kept engaged and the brake 156 is released the operation of the motor M1 brings about a movement of the operator member 152 along the Y axis. If, on the other hand, the brake 156 is kept engaged and the brake 154 is released, the operation of the motor 1 brings about a movement of the operator member 152 along the X axis.

Figure 23 shows a further variant of the invention for controlling two axes, one linear axis and one rotary axis, independently. The device of Figure 23 comprises two pulleys 140 and 142 with stationary axes, associated with motors M1 and M2, four pulleys 148 with stationary axes, and two pulleys 149 carried by a carriage which is translatable in the direction of the Y axis. One (or both) of the two pulleys 149 will constitute the rotary axis (or axes). Combined rotation of the pulleys 140 and 142 driven by the respective motors M1 and M2 results in a combined movement of the movable carriage along the Y axis and a rotation of the pulley 149 in a plane parallel to the plane X-Y.

The possibility of adding further axes of movement to the "variable cross" device with the motors nevertheless being kept in stationary positions will now be examined, as has already been done for the "variable H" device,.

Figure 24 shows schematically a device with four independent axes with four motors and with three transmission members 150, 158 and 160. The second transmission member 158 cooperates with a pair of stationary pulleys 162, one of which is associated with a motor M3, and with four pulleys 166, the axes of which are carried by the same slide which carries the pulleys 148 of the first transmission member 150. The return member 158 also cooperates with a transmission pulley 163 and with a pulley P3. Similarly, the third transmission member 160 cooperates with stationary pulleys 164, one of which cooperates with a motor M4, with pulleys 168 carried by the movable slide along the X axis, with a return pulley 169, and with a pulley P4. The pulleys P3

and P4 and the return pulleys 163 and 164 are carried by the carriage 138 which is movable relative to the slide in the direction of the Y axis.

With reference to Figures 25 and 26, the following definitions are given in addition to the definitions given above: [27]

ω_3: angular velocity of the pulley driven by the motor M3 in the sense indicated in Figure 25;

ω_{P3}: angular velocity of the pulley P3 in the sense indicated in Figure 25;

V_{P3}: peripheral linear velocity of the pulley of the motor M3 owing to ω_3;

V_{PP3}: overall peripheral linear velocity of the pulley P3;

ω_4: angular velocity of the pulley driven by the motor M4 in the sense indicated in Figure 26;

ω_{P4}: angular velocity of the pulley P4 in the sense indicated in Figure 26;

V_{P4}: peripheral linear velocity of the pulley of the motor M4 owing to ω_4;

V_{PP4}: overall peripheral linear velocity of the pulley P4.

The following kinematic equations for the third and fourth axes are obtained in the same manner as those obtained for the "variable H" device:

$$\begin{cases} V_{P3} = V_{P1} + V_{PP3} \\ V_{PP3} = -V_{P1} + V_{P3} \end{cases} \qquad [28]$$

$$\begin{cases} V_{P4} = -V_{P2} + V_{PP4} \\ V_{PP4} = V_{P2} + V_{P4} \end{cases} \qquad [29]$$

The rotations of the pulleys P3 and P4 constitute rotary axes and can be used to achieve a vertical axis X and a rotary axis associated with the vertical axis, as shown in Figure 27. The device shown in Figure 27 is conceptually identical to that described above with reference to Figure 10. In Figure 27, elements corresponding to those of the device of Figure 10 have been indicated by reference numerals increased by one hundred.

Again like the "variable H" device, the arrangement of Figure 28 may be used for the second transmission member 158 in order to achieve a movement along the Z axis without the use of the male and female screw system of Figure 27. In this drawing, two pulleys, indicated 186, are rotatable in a plane parallel to the plane Y-Z, their axes being carried by the carriage which is movable in the direction of the Y axis relative to the pulleys 166. The points for the anchorage of the transmission member 158 to the body (not shown) movable along the Z axis are indicated P.

The arrangement of Figure 29 may be used for the third transmission member 160 to provide a rotary axis in combination with the vertical Z axis. In this drawing, two pulleys, indicated 190, are rotatable in a plane parallel to the plane Y-Z and are carried by the carriage 138 which is movable in the direction of the Y axis relative to the pulleys 168. Three pulleys 192 and 194, rotatable in a plane parallel to the plane Y-Z, are carried by the body movable in the direction of the Z axis. Finally, a pulley 196 constituting the rotary axis is rotatable in a plane parallel to the plane X-Y

and is carried by the body movable in the direction of the Z axis.

Again like the "variable H" device, it is possible to control three axes with only two motors with the use of the arrangement shown in Figures 30 and 31.

With reference to these drawings, a single flexible transmission member 150 cooperates with two pulleys 140, 142 driven by motors M1 and M2. The transmission member 150 also cooperates with the pulleys 148 carried by the slide 134 and with a pulley 149 and a pulley P3, the latter two being carried by the carriage 138 which is movable in the direction of the Y axis relative to the slide 134. The pulley P3 is associated with a brake 204 which, when it is engaged, locks the rotation of the pulley. A further brake 202, when activated, locks the movement of the slide 134 relative to the base 130. The rotary axis of the pulley P3 can be transformed into a linear axis in the Z direction by means of a male and female screw mechanism.

The two brakes 202 and 204 are operated alternatively so that, when the brake 204 which locks the rotation ω_{P3} is operated, movements along the X and Y axes are possible and when the brake 202 is operated the rotation ω_{P3} and the movement along the axis Y are possible.

A system with three axes and with two motors can also be formed on the basis of the arrangement of Figure 28 by the provision of brakes which can alternatively lock the movement along the X axis or the movement along the Z axis.

Again with reference to Figure 28, with the provision, on the other hand, of a single motor associated with one of the pulleys 162 and three independent brakes one operating on each axis, if two of the three brakes are kept engaged and the third is released, the rotation of the motor imparts a movement to the axis associated with the released brake, thus forming a system with three axes and only one motor.

However, with reference to the arrangement of Figure 29, it is possible, if both of the pulleys 164 are driven, to produce a system with four non-independent axes using only two motors. In this case, it is necessary to provide a brake which locks the rotation of the pulley 196, a brake which locks the movement along the Z axis and a brake which locks the movement along the X axis. If the rotation of the pulley 196 and the movement along the Z axis, are simultaneously locked, the rotation of the two motors brings about a movement of the operator member associated with the pulley 196 in a plane parallel to the plane X-Y. If the movement along the X axis and the rotation of the pulley 196 are locked, however, a movement of the operator member in a plane Y-Z is achieved. Finally, if the movements along the X and Z axes are locked, a rotary movement of the pulley 196 and its movement along the Y axis will be achieved.

Again like the "variable H" device, it is also possible for the "variable cross" device to have several operator members operating in the same working area, for example, according to the arrangements shown in Figures 32-34. In the version of Figure 32 there are two slides 134 movable along the same guides 132. With this arrangement, two

transmission members 150 are used, each being associated with two motors. Another system is shown in Figure 33, in which the same slide 134 carries two carriages 138 movable independently of one another in the direction of the Y axis relative to the slide 134. The pairs of axes thus obtained are not independent, since both make use of the same X axis. In this case, two transmission members 150 are required, one of which cooperates with two motors M1 and M2 whilst one motor M3 suffices for driving the second transmission member.

Finally, the two schemes of Figures 32 and 33 may be combined to produce four pairs of axis X-Y which are independent in pairs as shown in Figure 34. For this arrangement, six motors and four transmission members 150 are required.

Finally, with reference to Figure 35, the basic arrangement of Figure 21 may be modified by the movement of the motors M1 and M2 inwardly and of the pulleys 148 outwardly. In the arrangement of Figure 35, the motors M1 and M2 associated with the pulleys 140 and 142 are intended to be in stationary positions, whilst the pulleys 148 can move along the X axis simultaneously and without relative movements between them, the pulleys 149 and the anchorage points P being fixed to a table which is movable parallel to the plane X-Y. The rotation of the pulleys 140 and 142 brought about by the motors M1 and M2 causes a movement of the table in the plane X-Y with kinematic behaviour identical to that relating to the arrangement of Figure 21.

CLAIMS

1. A transmission device, characterized in that it comprises stationary drive means (M1, M2, M3, M4, M5, M6) cooperating with at least one flexible transmission member (50, 58, 60; 150, 158, 160) which can bring about the movement of an operator member (52; 152) along at least two axes.

2. A device according to Claim 1, characterized in that it comprises:

- a stationary base (30; 130) having guide means (32; 132).

- a first movable element (34; 134) slidable along the first guide means (32; 132) and having second guide means (36; 136),

- a second movable element (38; 138) slidable along the second guide means (36; 136),

- the at least one flexible transmission member (50, 58, 60; 150, 158, 160) being operatively associated with the second movable element (38; 138) and cooperating with first return means (40, 42, 44, 46, 62, 64; 140, 142, 162, 164) carried by the base (30; 130) and with second return means (48, 66, 68; 148, 166, 168) carried by the first movable element (34; 134).

3. A device according to Claim 1 or Claim 2, characterized in that the at least one flexible transmission member (50, 58, 60) extends along a

generally H-shaped path the configuration of which is variable in dependence upon the movement of the operator member (52; 152) in a plane.

4. A device according to Claim 1 or Claim 2, characterized in that the at least one flexible transmission member (150, 158, 160) extends along a generally cross-shaped path, the configuration of which is variable in dependence on the movement of the operator member (152) in a plane.

5. A device according to any one of the preceding claims, characterized in that it comprises at least one further flexible transmission member (58, 60; 158, 160) associated with its own stationary motor (M3, M4) for bringing about the movement of the operator member (52; 152) along at least one further axis in addition to the first two.

6. A device according to any one of the preceding claims, characterized in that it comprises a pair of drive members (M1, M2) cooperating with the same flexible transmission member (50; 150) which can bring about the movement of the operator member (52; 152) along two axes.

7. A device according to Claim 6, characterized in that the flexible transmission member (50; 150) extends along a path the configuration of which can vary when the drive means impart different linear velocities of advance at different points of the transmission member (50; 150).

8. A device according to any one of Claims 1 to 5,

characterized in that it comprises a single drive member associated with the or each flexible transmission member (50; 150) and in that it comprises braking means (54, 56, 102, 104; 154, 156, 202, 204) for selectively preventing the movement of the operator member along at least a first and a second axis.

9. A device according to any one of Claims 1 to 5, characterized in that it comprises a pair of drive members cooperating with the same flexible transmission member (50; 150) and braking means (102, 104; 202, 204) for selectively preventing the movement of the operator member (52; 152) along selected axes.

10. A device according to any one of the preceding claims, characterized in that it comprises at least one pair of movable elements (34, 38; 134, 138) movable along the same guide (32, 34; 132; 134).

FIG. 1

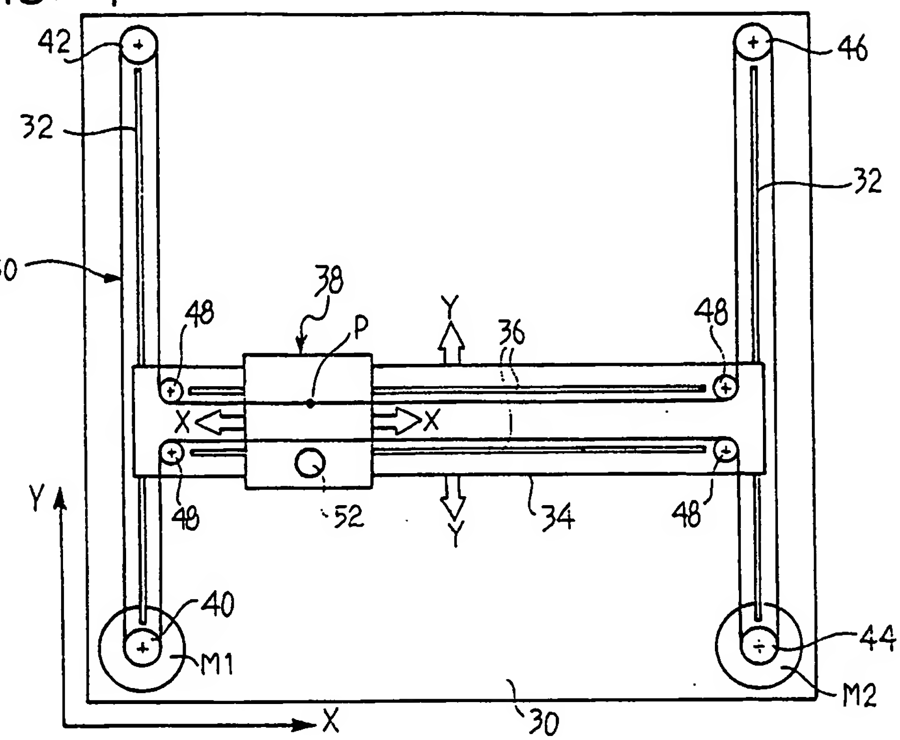

42
46
32
32
50
38
P
Y
36
48
48
X
X
48
48
52
34
Y
Y
40
44
M1
M2
X
30

FIG. 2

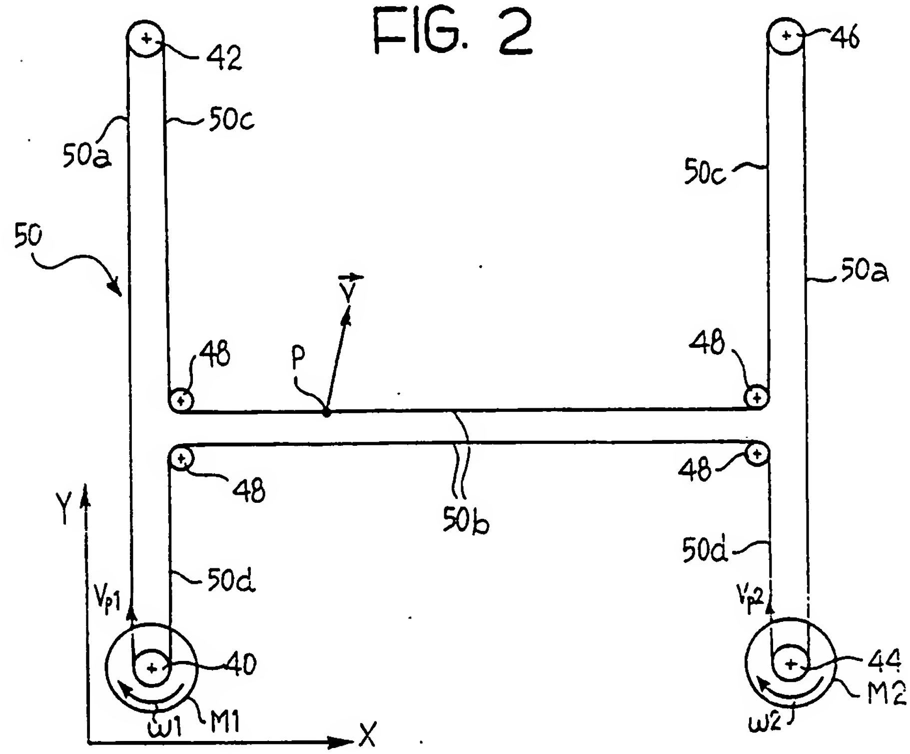

42
46
50a
50c
50c
50a
50
48
48
P
$\vec{V}$
48
48
50b
Y
50d
50d
V_{p1}
V_{p2}
40
44
M2
ω1
M1
ω2
X

FIG. 3

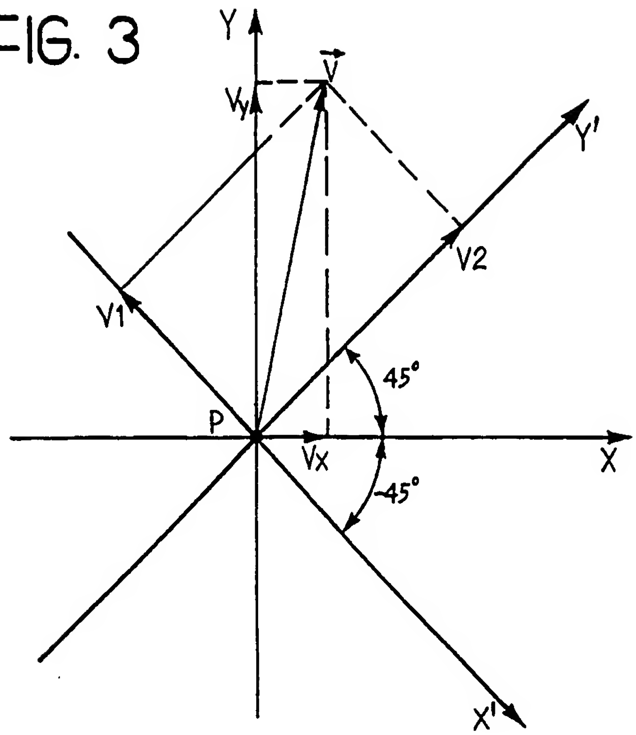

Y
$\vec{V}$
Vy
Y'
V2
V1
45°
P
Vx
X
-45°
X'

FIG. 4

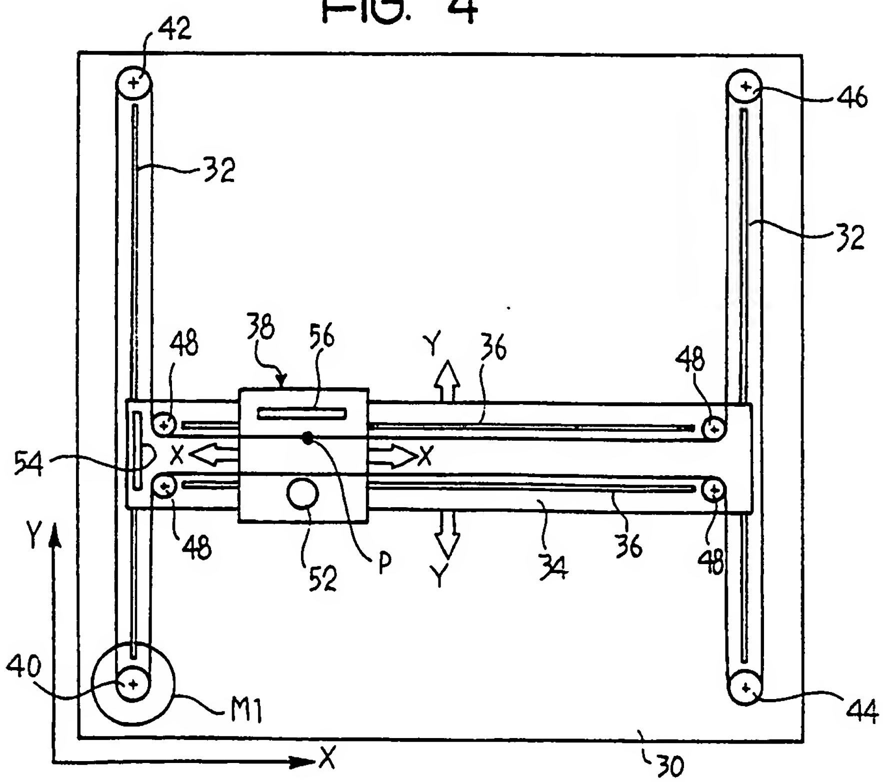

42
46
32
32
38
56
48
Y
36
48
54
X
X
Y
48
52
P
Y
34
36
48
40
M1
44
X
30

FIG. 5

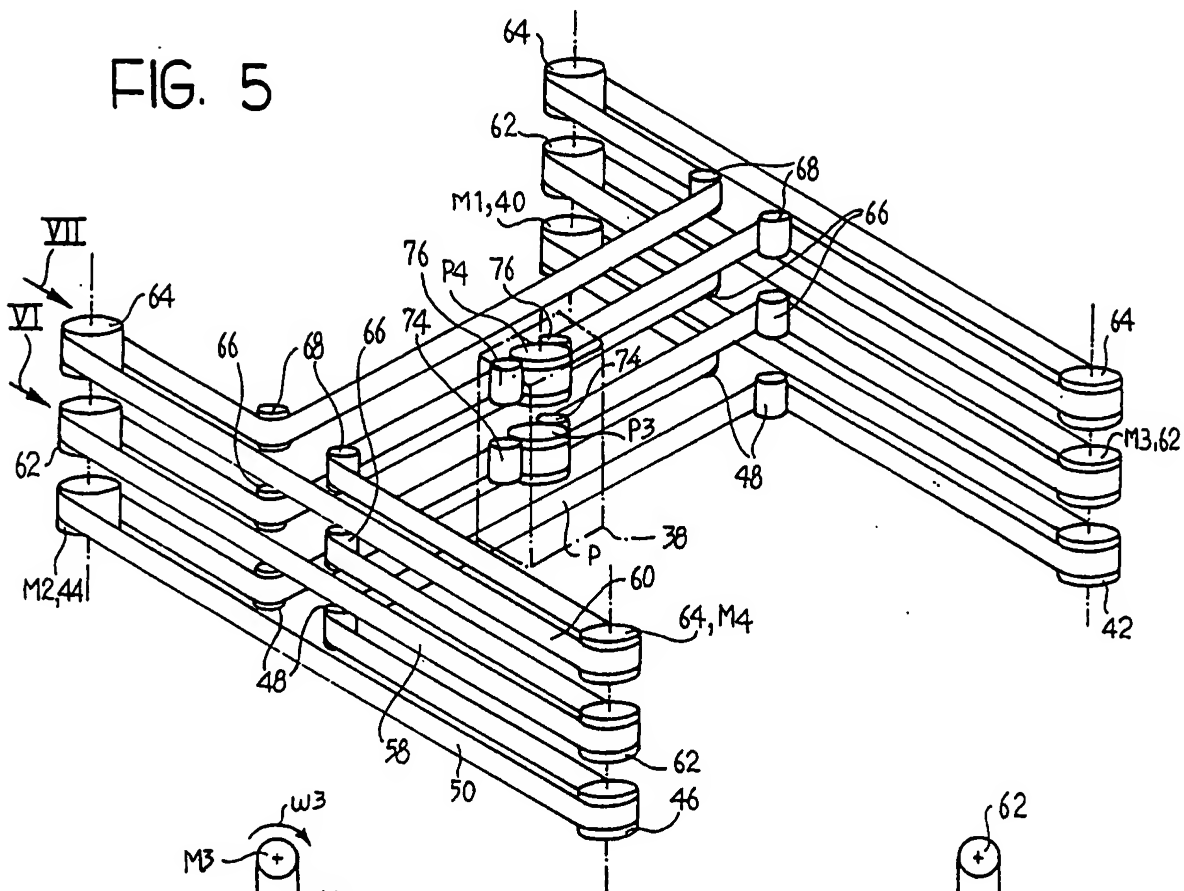

64
62
M1,40
68
66
76
P4
76
VII
VI
64
66
68
66
74
74
P3
64
M3,62
48
62
M2,44
P
38
60
64,M4
42
48
58
50
62
46

FIG. 6

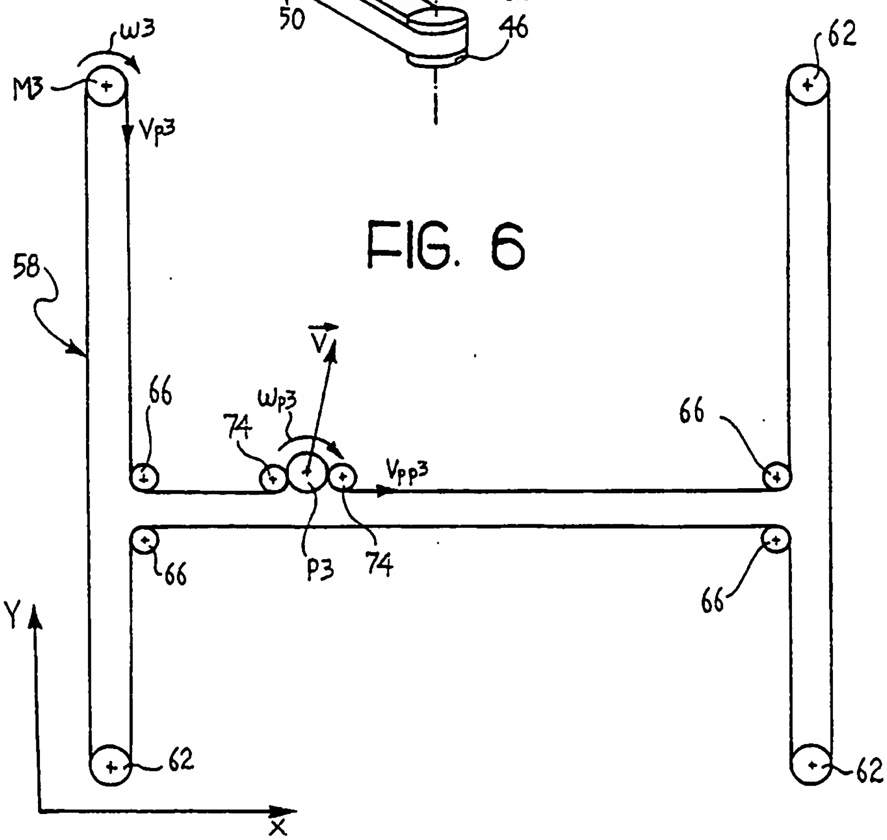
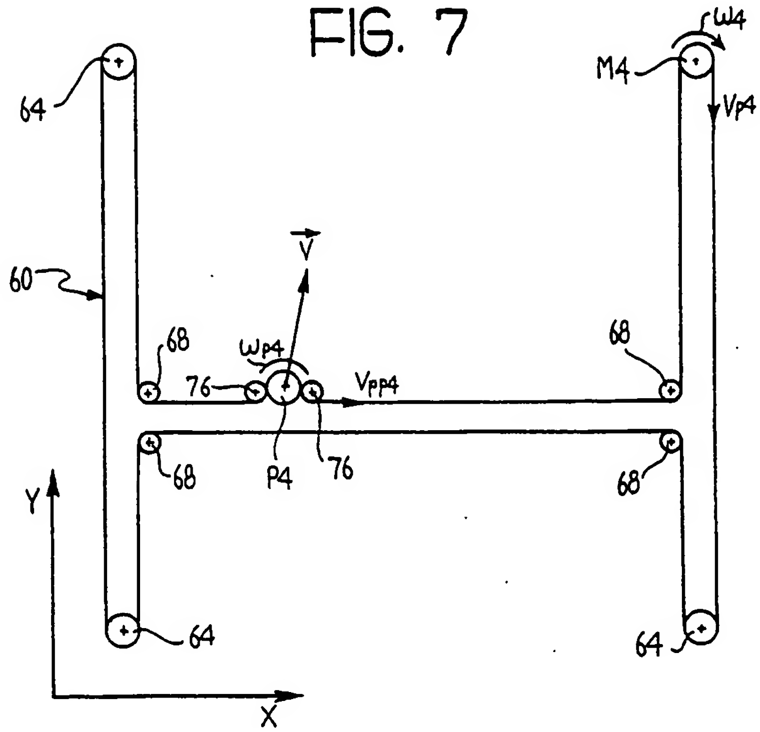
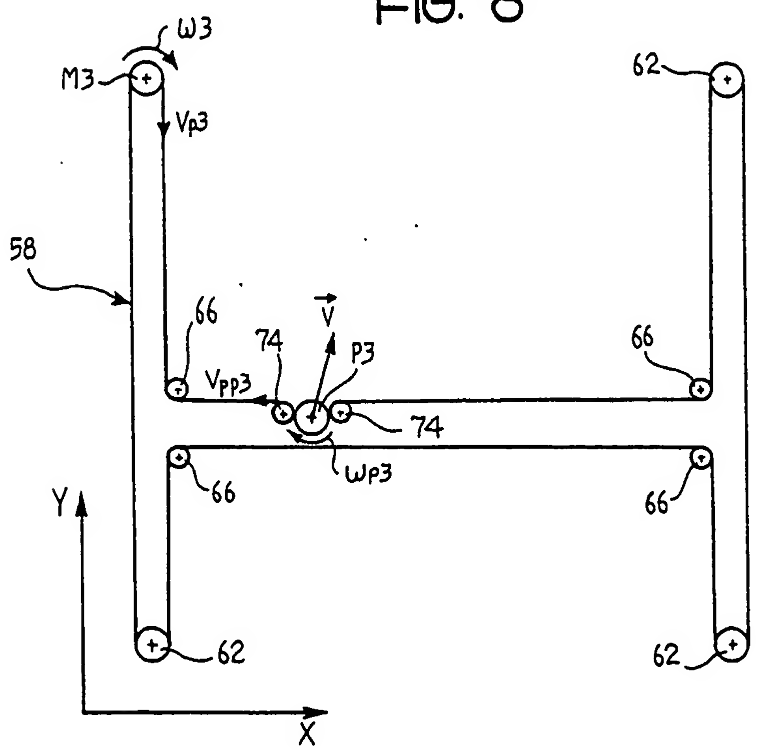

ω3
M3
Vp3
62
58
V
66
ωp3
74
Vpp3
66
66
P3
74
66
Y
62
62
X

FIG. 7



ω4
M4
Vp4
64
60
V
68
ωp4
76
Vpp4
P4
76
68
68
68
Y
64
64
X

FIG. 8



ω3
M3
Vp3
62
58
66
74
V
P3
66
Vpp3
74
ωp3
66
66
Y
62
62
X

FIG. 9

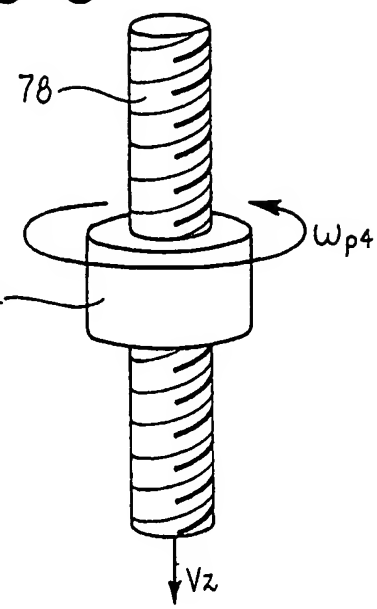


FIG. 10

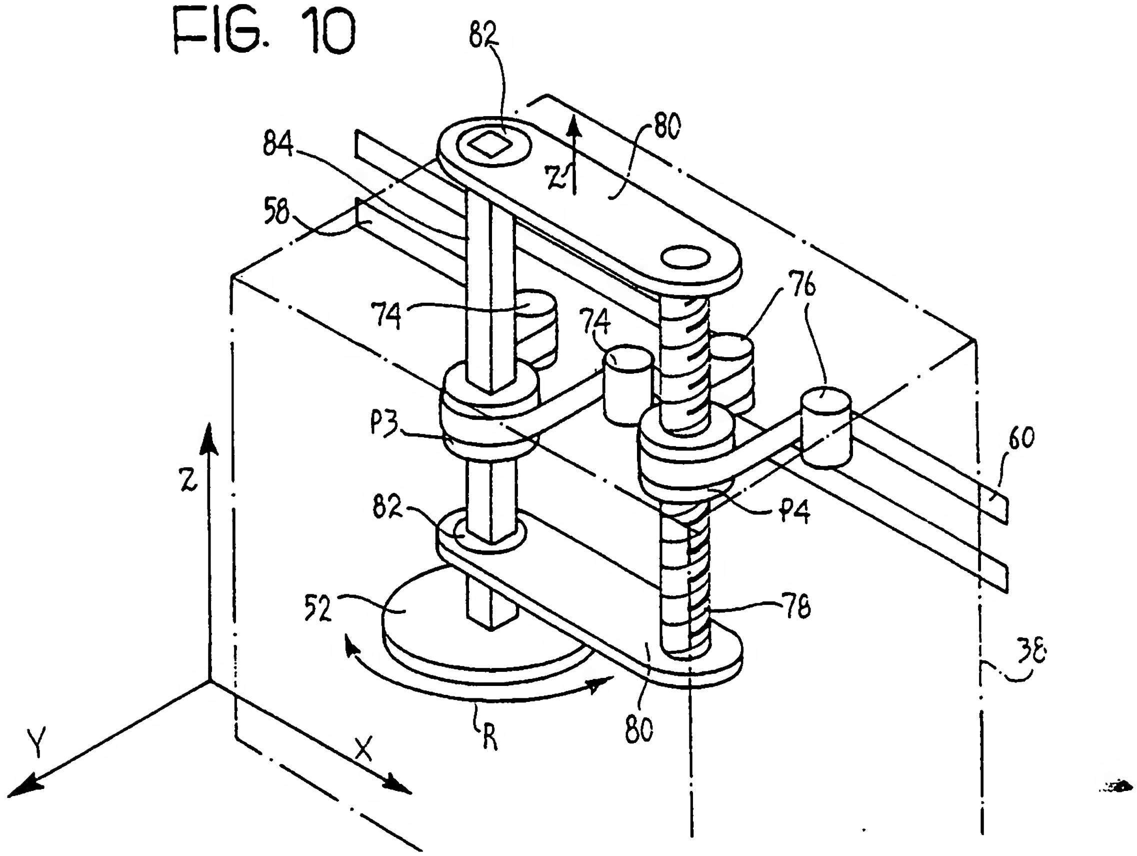


FIG. 11

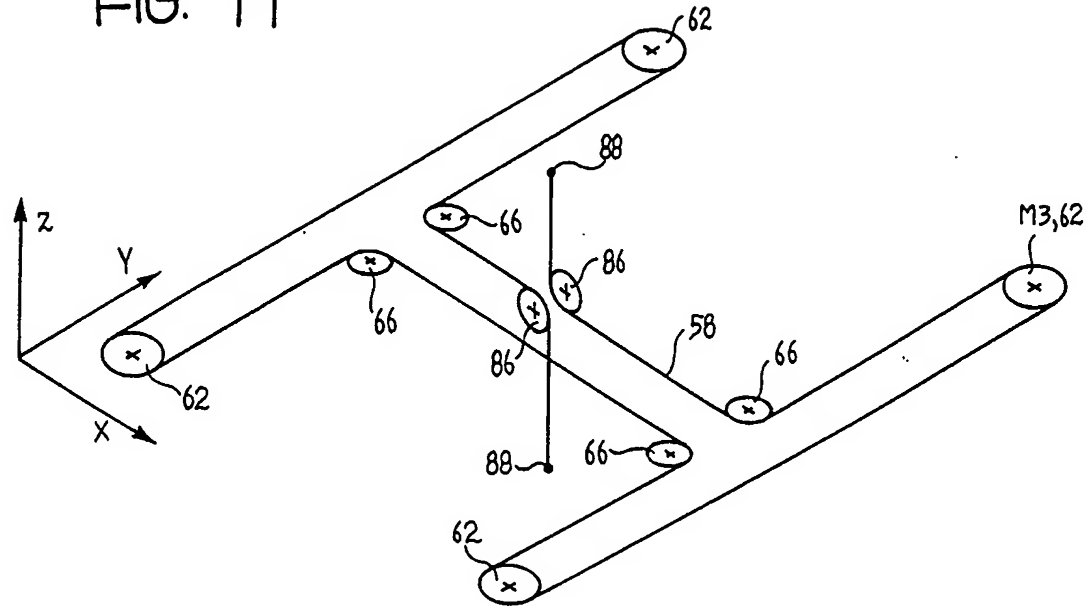

62
88
66
Z
Y
86
M3,62
66
58
86
66
62
X
88
66
62

FIG. 12

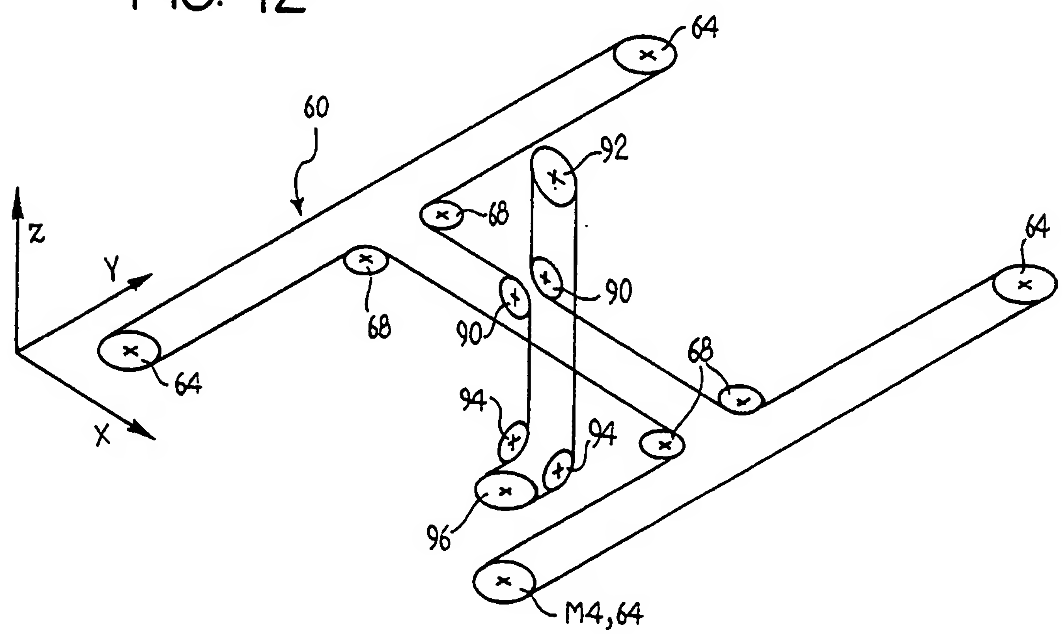

64
60
92
68
Z
Y
90
64
68
90
68
64
X
94
94
96
M4,64

FIG. 13

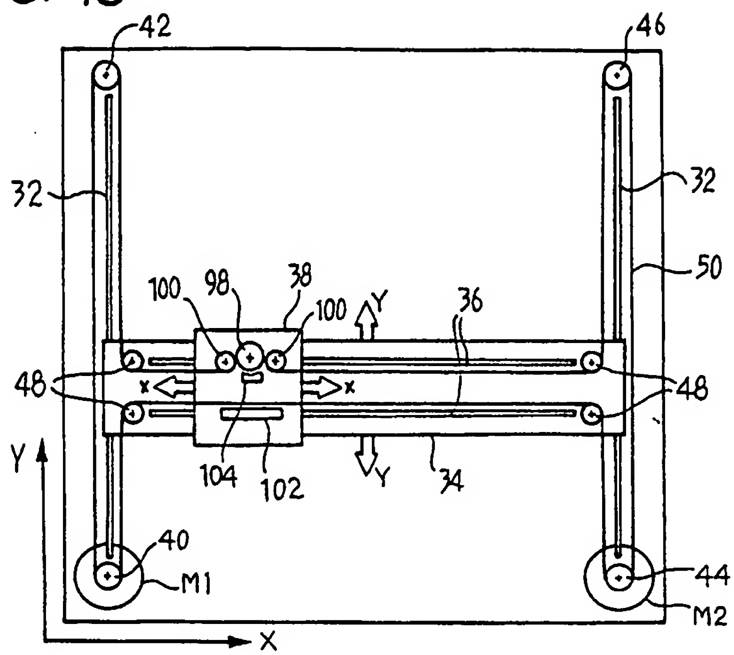

42
46
32
32
50
100
98
38
100
Y
36
48
x
x
48
Y
104
102
Y
34
40
M1
44
M2
X

FIG. 14

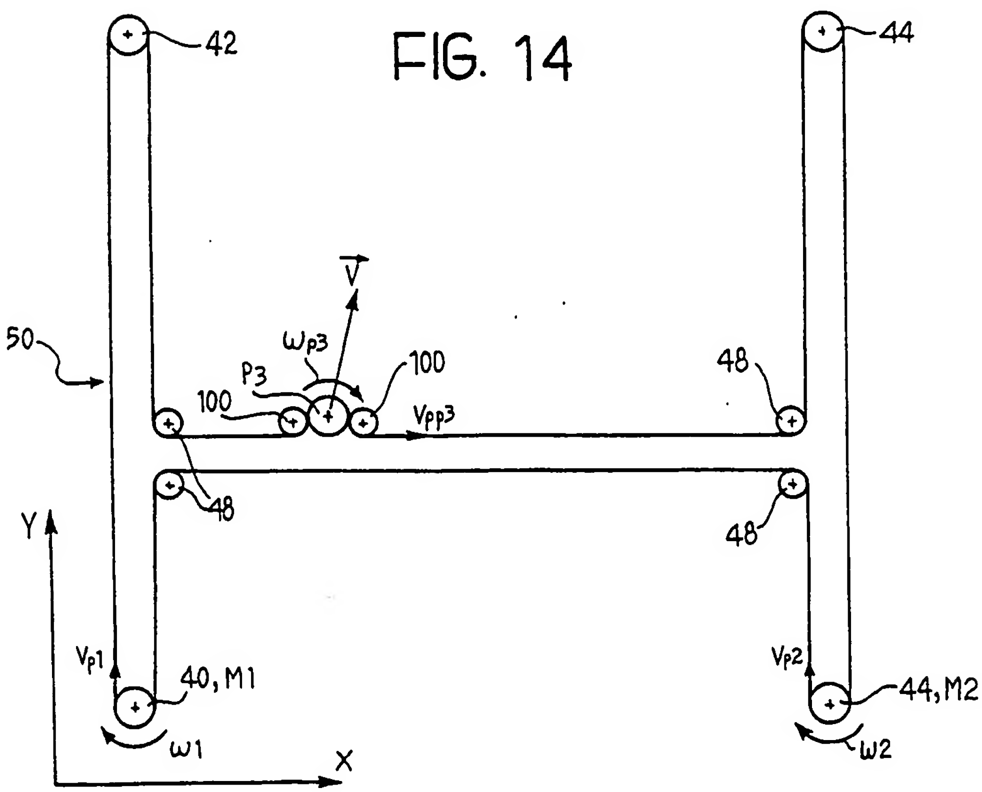

42
44
V
50
ωp3
P3
100
100
Vpp3
48
48
48
Y
48
Vp1
40, M1
Vp2
44, M2
ω1
ω2
X

FIG. 15.

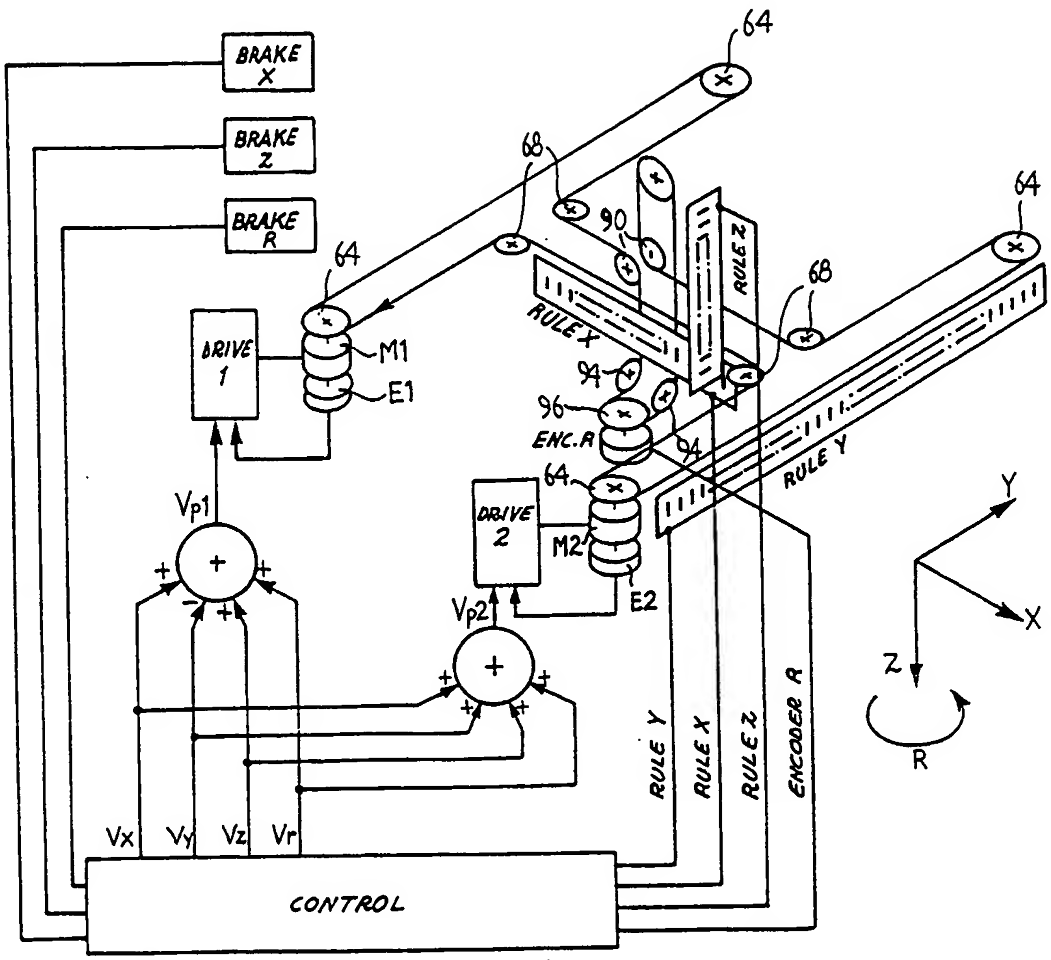

64
BRAKE X
BRAKE Z
BRAKE R
68
90
RULE Z
64
64
68
RULE X
DRIVE 1
M1
E1
94
96
ENC. R
94
RULE Y
64
DRIVE 2
M2
E2
Vp1
Vp2
Y
X
Z
R
RULE Y
RULE X
RULE Z
ENCODER R
Vx
Vy
Vz
Vr
CONTROL

FIG. 16

BRAKE X	BRAKE Z	BRAKE R	FREE AXES	Vp 1	Vp 2	ZEROED VELOCITIES
DISENGAGED	ENGAGED	ENGAGED	Y-X	$V_x - V_y$	$V_x + V_y$	$V_z = V_r = 0$
ENGAGED	DISENGAGED	ENGAGED	Y-Z	$V_z - V_y$	$V_z + V_y$	$V_x = V_r = 0$
ENGAGED	ENGAGED	DISENGAGED	Y-R	$V_r - V_y$	$V_r + V_y$	$V_x = V_z = 0$

FIG. 17

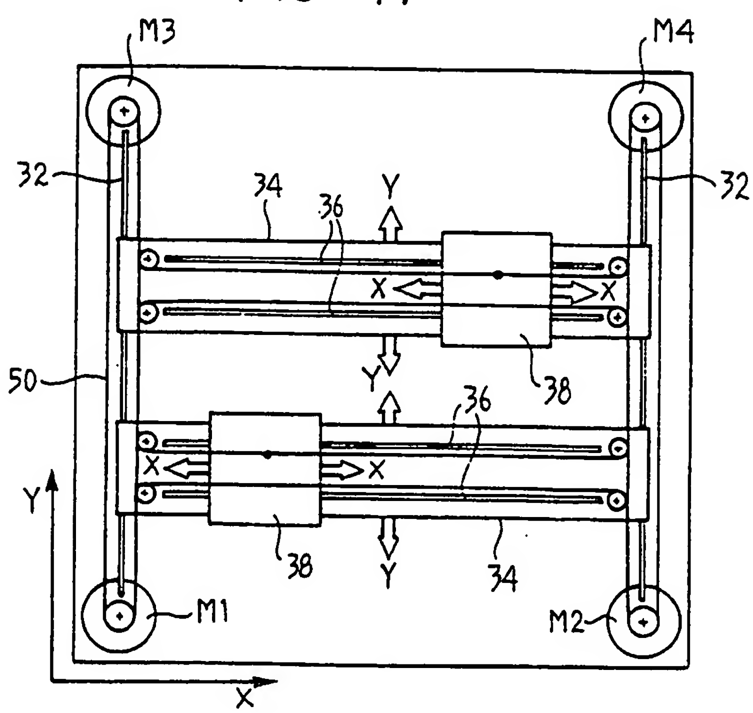


FIG. 18

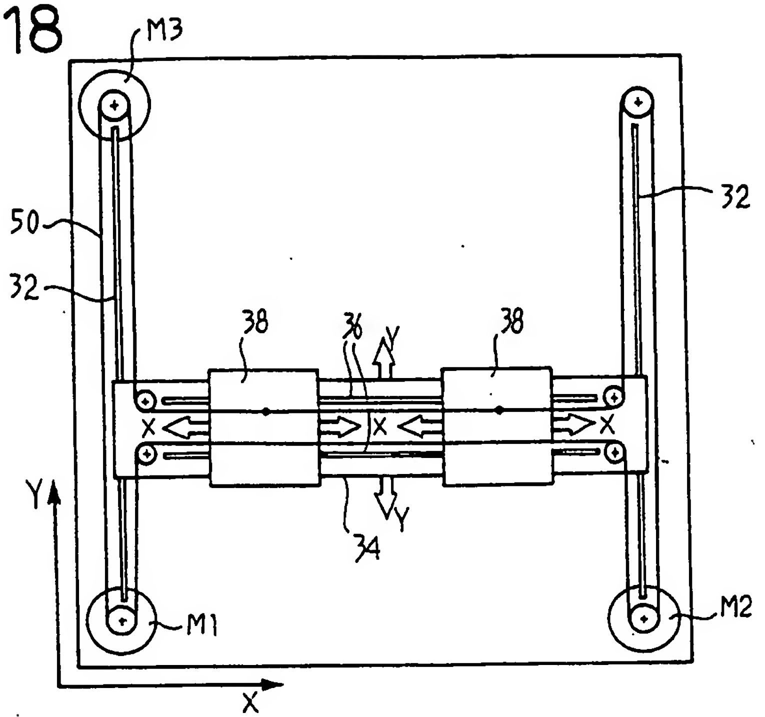

M3
32
50
32
38
36
Y
38
X
X
X
Y
Y
34
M1
M2
X

FIG. 19

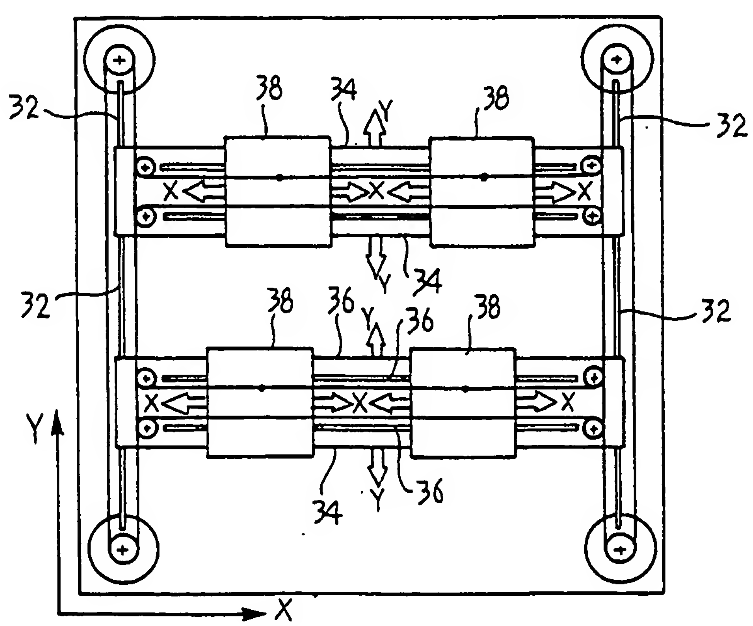

32
38
34
Y
38
32
X
X
X
Y
34
32
38
36
Y
36
38
32
X
X
X
Y
34
Y
36
X

FIG. 20

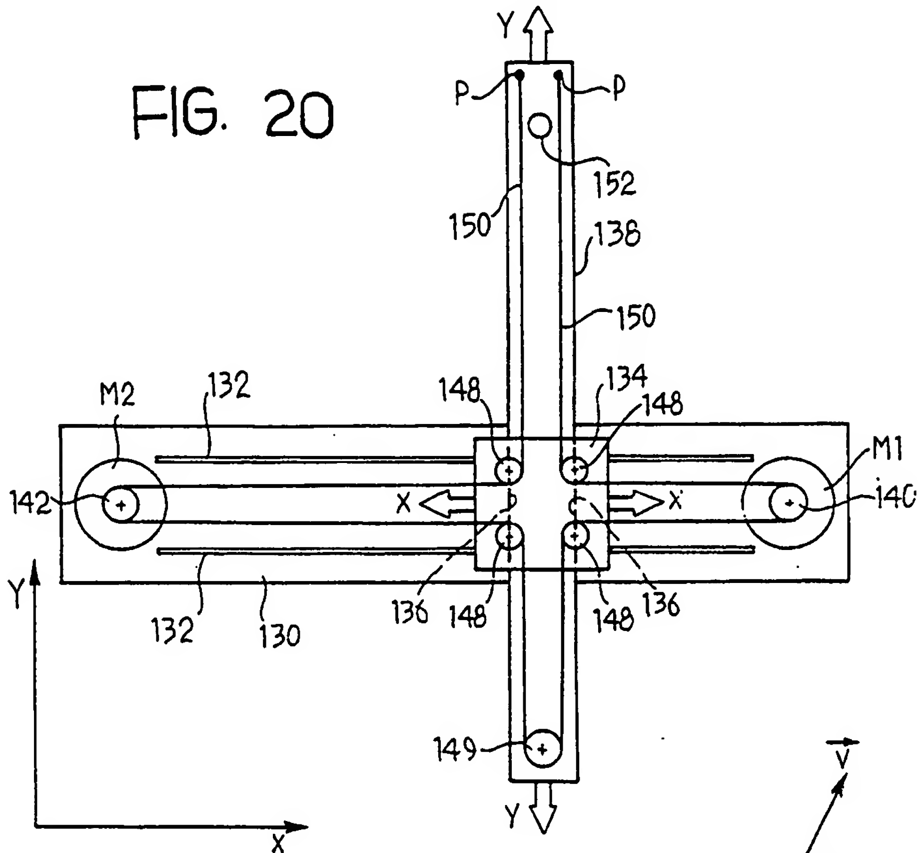

Y
P
P
152
150
138
150
132
M2
148
134
148
M1
142
X
X
140
Y
136
148
148
136
132
130
149
Y
X

FIG. 21

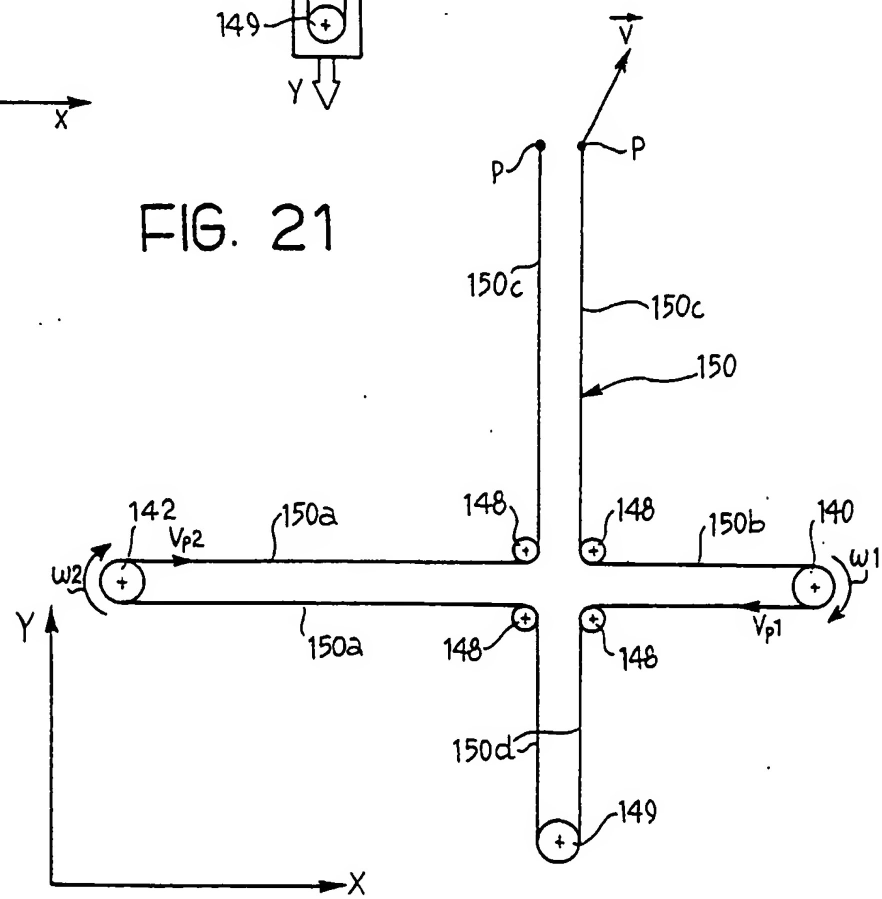

V
P
P
150c
150c
150
142
148
148
150b
140
V_{p2}
150a
ω1
ω2
Y
150a
148
148
V_{p1}
150d
149
X

FIG. 22

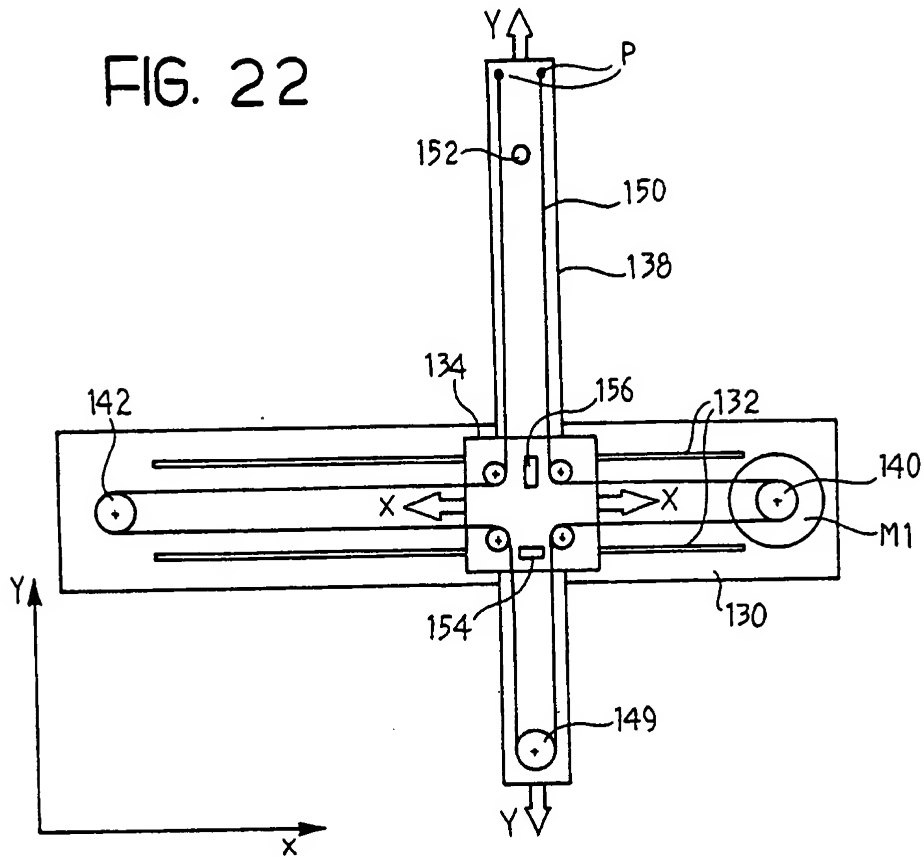

Y
P
152
150
138
134
156
132
142
140
X
X
M1
Y
154
130
149
Y
x

FIG. 23

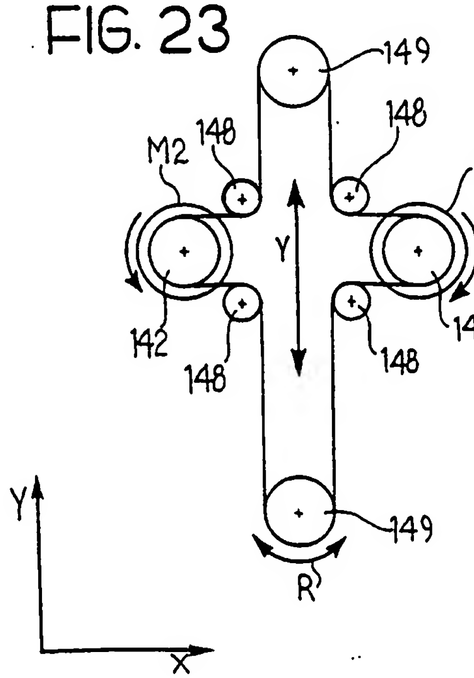

149
148
148
M2
M1
Y
142
140
148
148
Y
149
R
x

FIG. 24

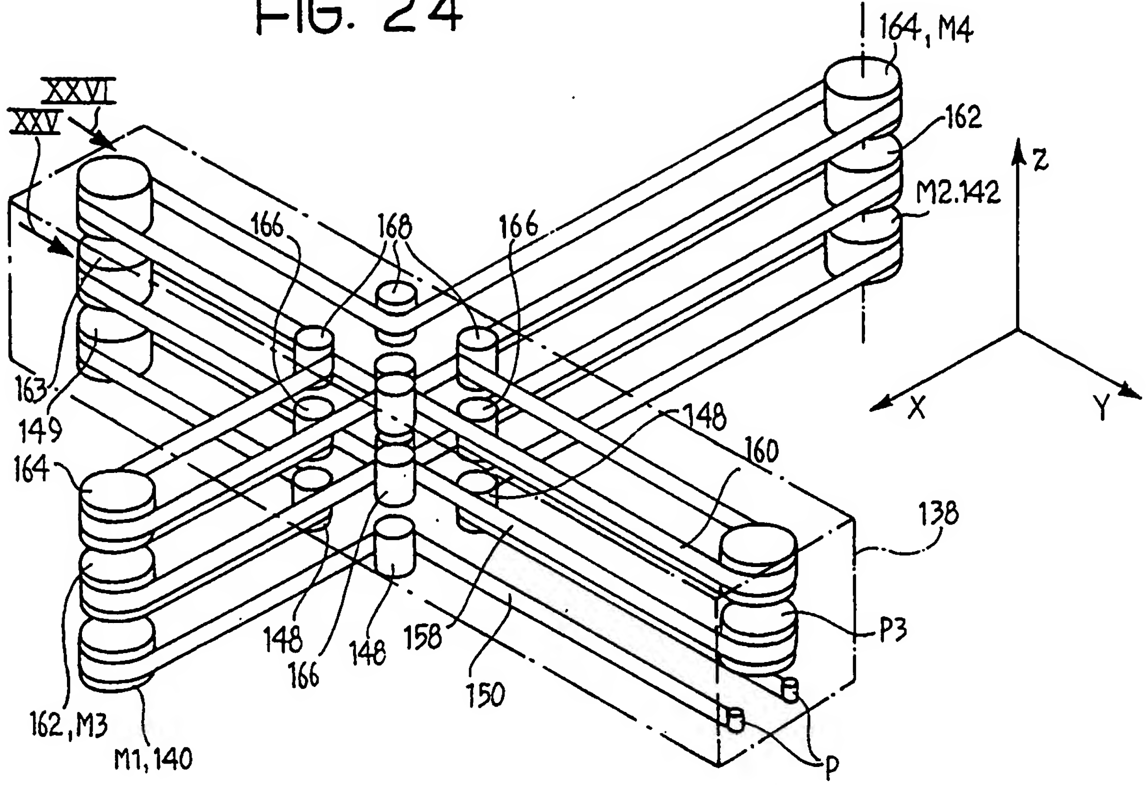

164, M4
162
M2.142
Z
X
Y
XXVI
XXV
166
168
166
163
149
164
148
160
138
P3
148
166
148
158
150
162, M3
M1, 140
P

FIG. 25

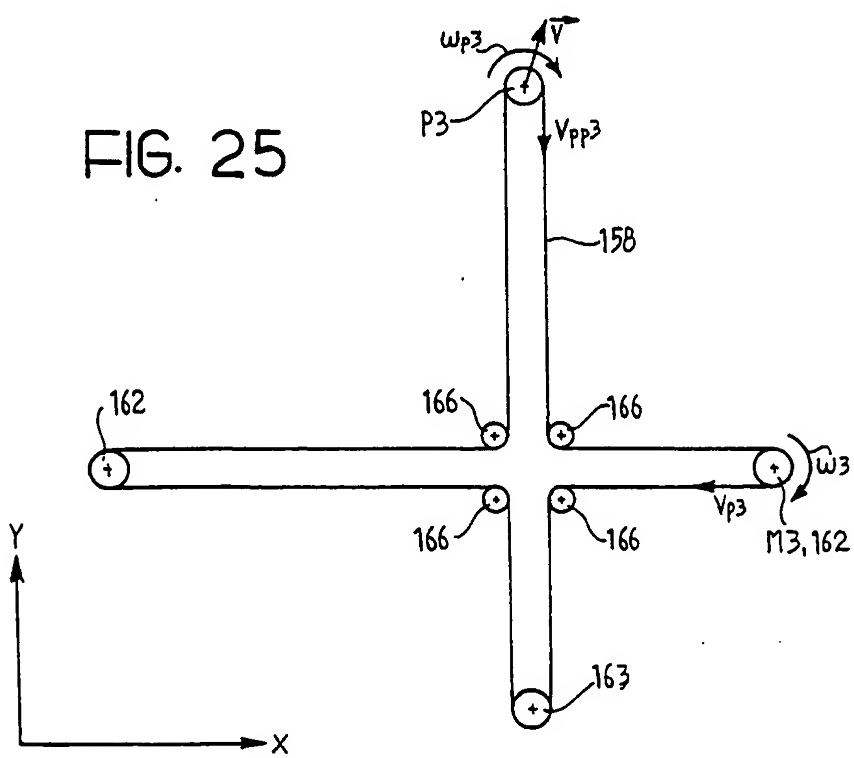

ωp3
V
P3
Vpp3
158
162
166
166
166
166
ω3
Vp3
M3, 162
163
Y
X

FIG. 26

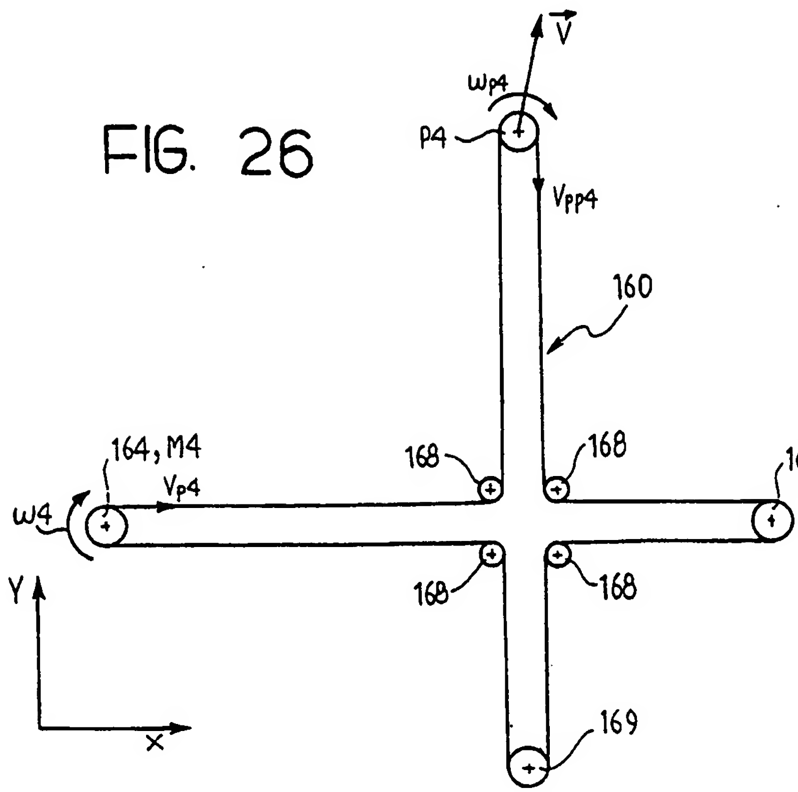

V
ωP4
P4
VPP4
160
164, M4
VP4
ω4
168
168
164
168
168
Y
X
169

FIG. 27

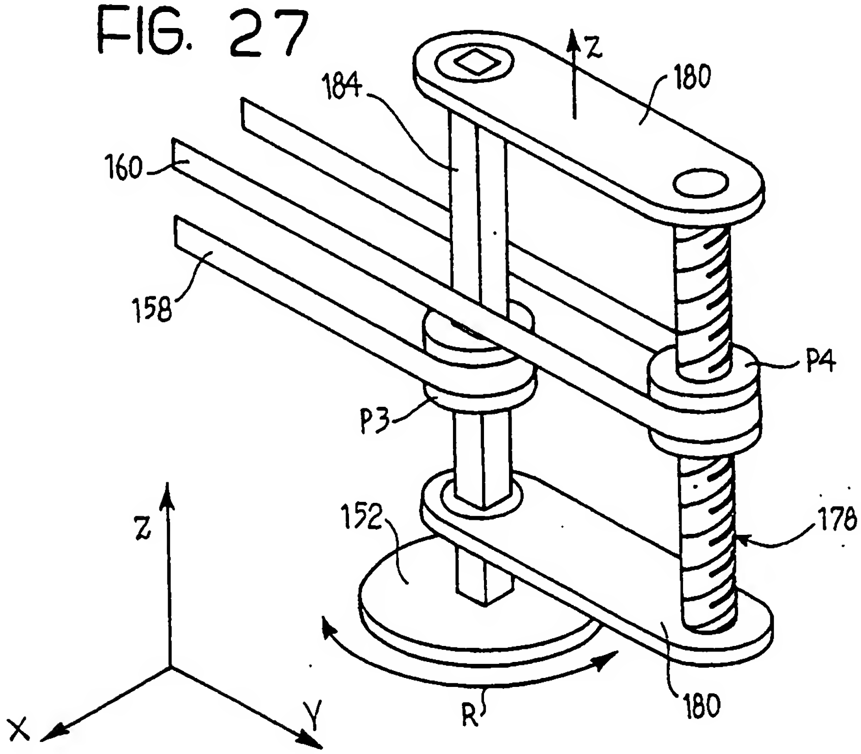

Z
180
184
160
158
P4
P3
Z
152
178
X
Y
R
180

FIG. 28

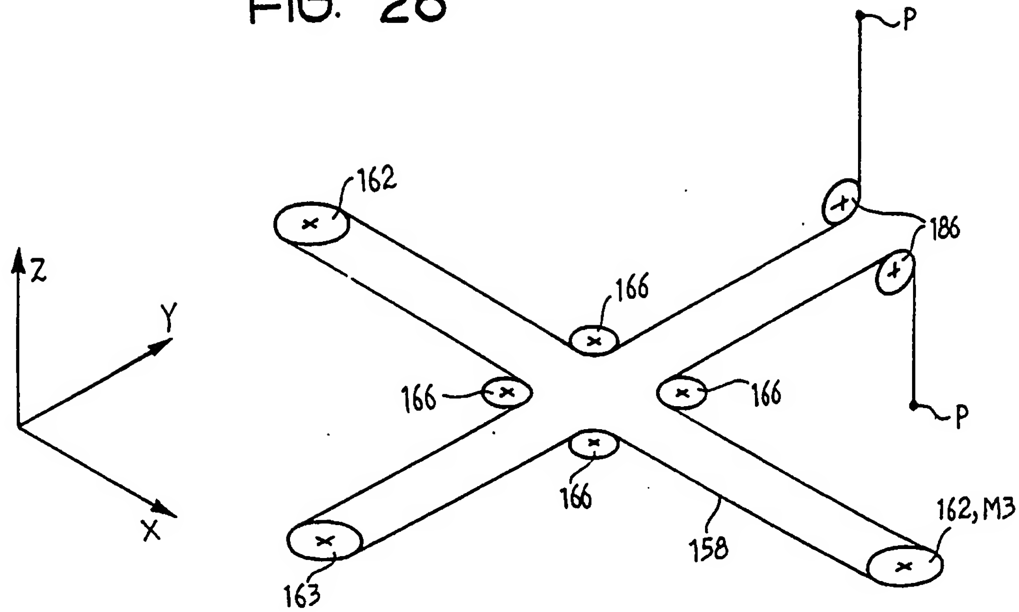

P
162
186
Z
Y
166
166
166
P
166
X
162, M3
158
163

FIG. 29

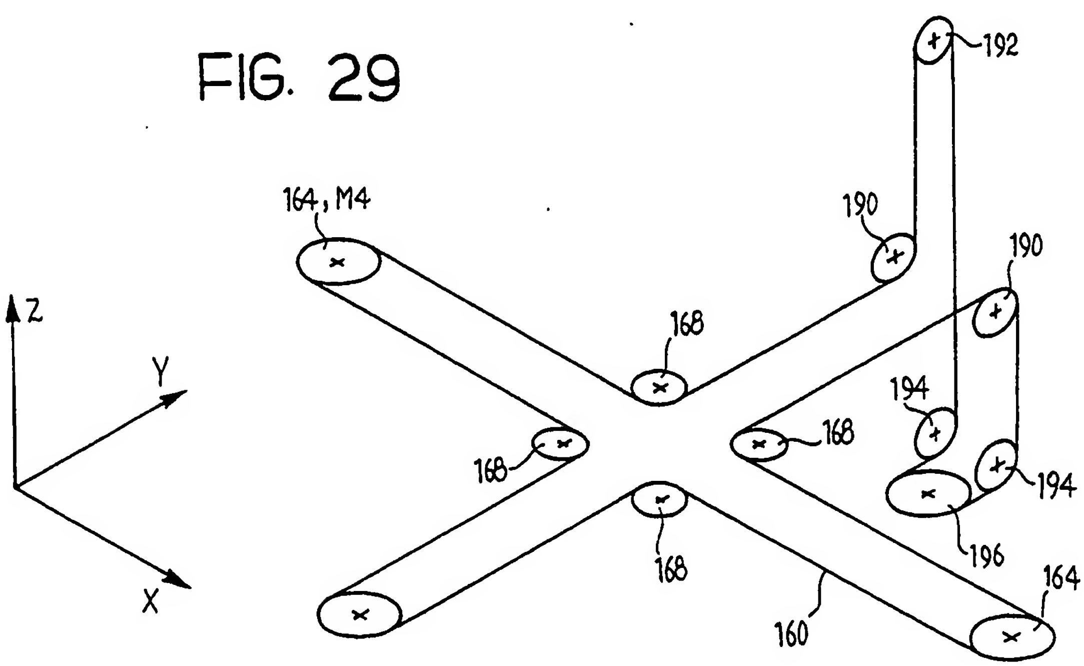

192
164, M4
190
190
Z
168
Y
194
168
168
194
196
168
164
X
160

FIG. 30

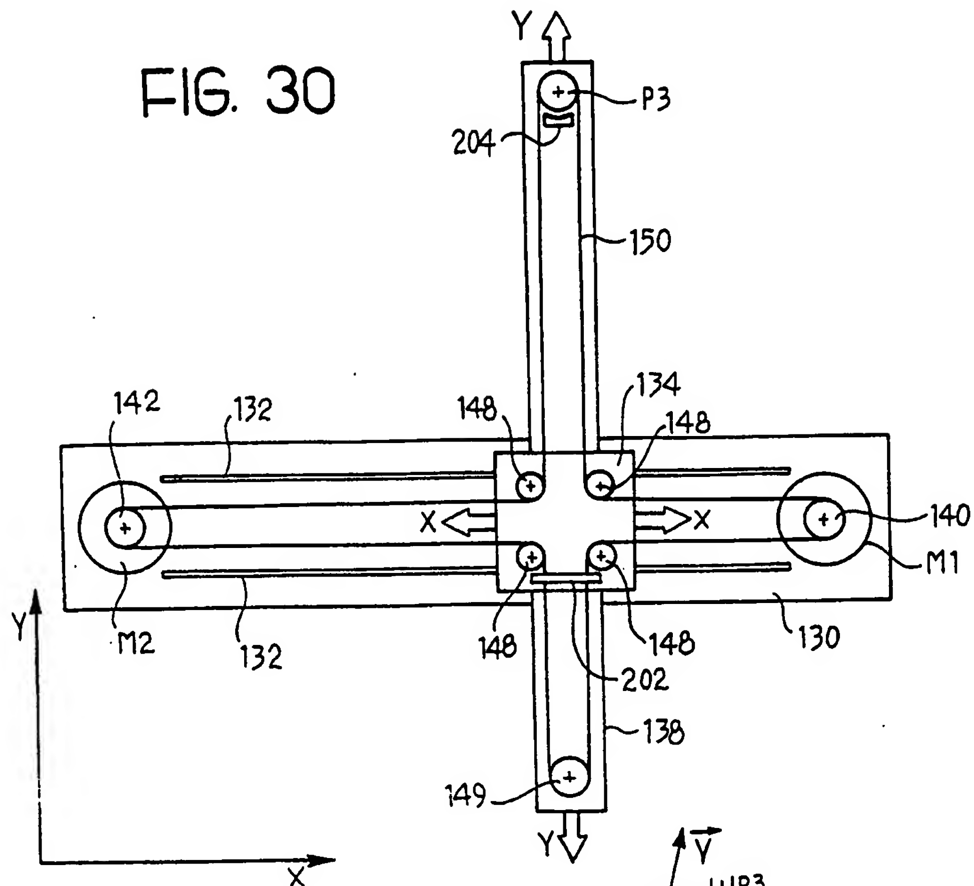

Y
P3
204
150
142
132
148
134
148
X
X
140
M1
Y
M2
132
148
148
202
130
138
149
Y
X

FIG. 31

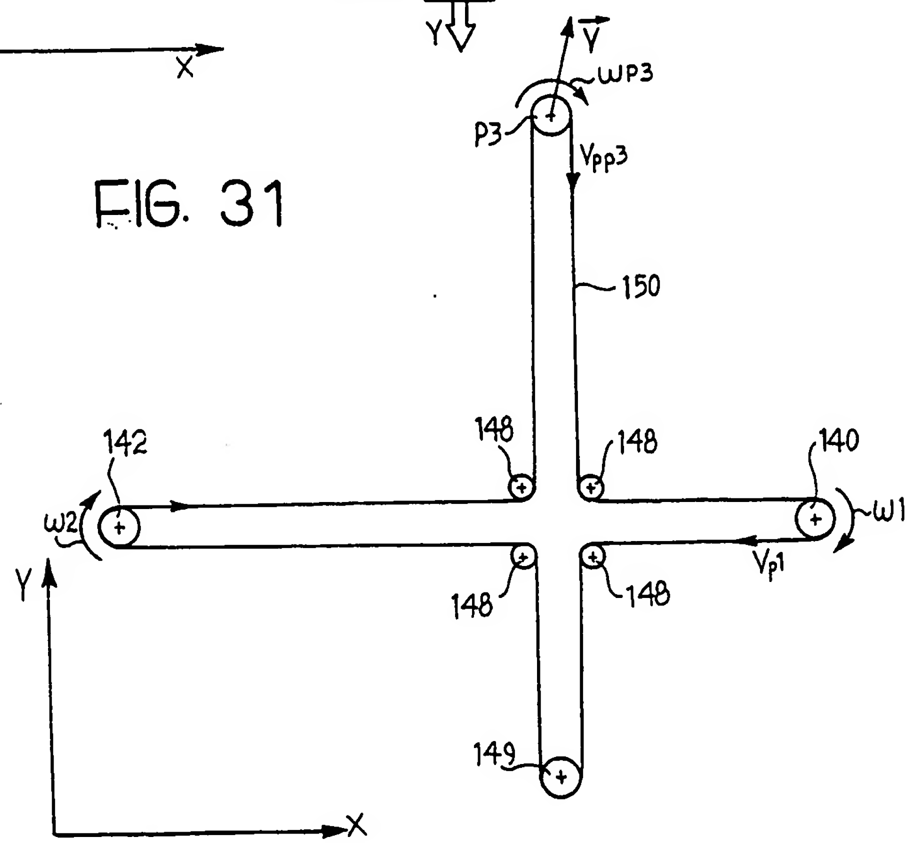

Y
ωP3
P3
Vpp3
150
142
148
148
140
ω2
ω1
Vp1
Y
148
148
149
X

FIG. 32

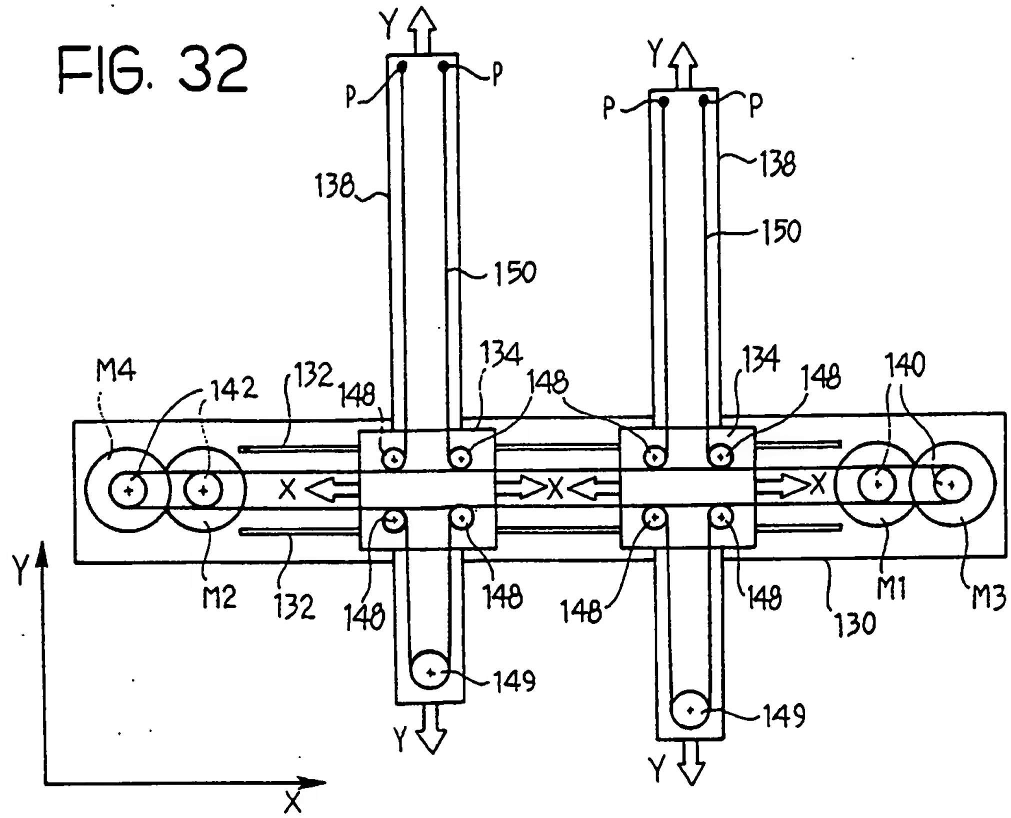

Y
P
P
138
150
M4
142
132
148
134
140
X
M2
M1
M3
130
149
Y
X

FIG. 33

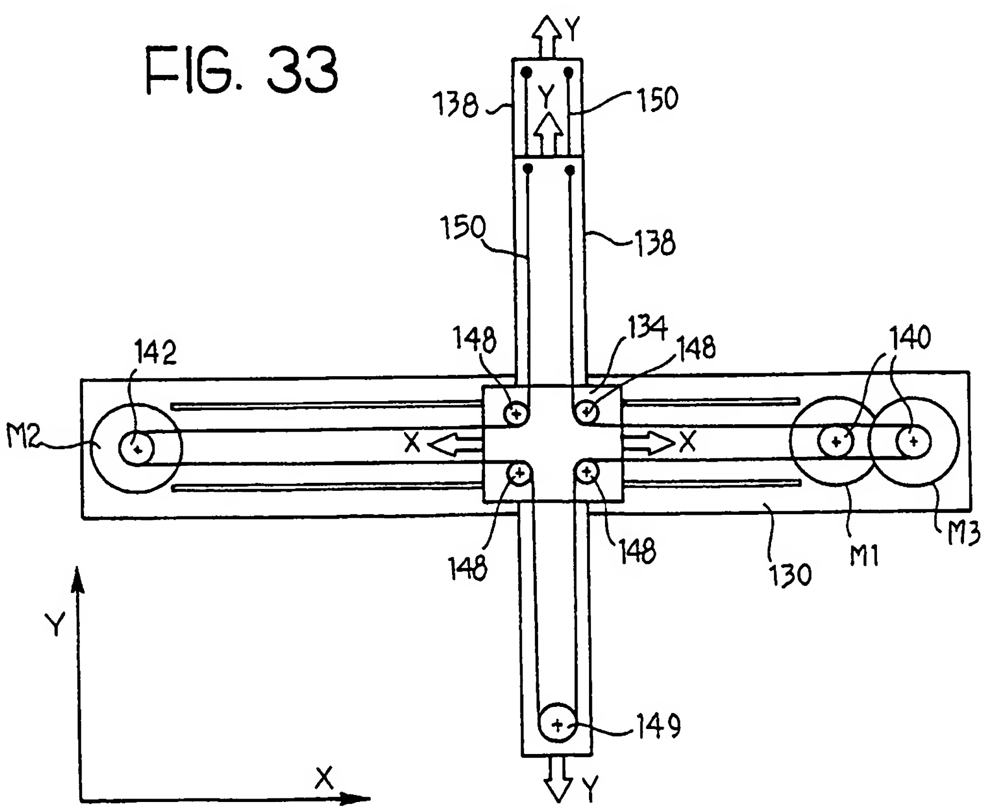

Y
138
150
148
134
142
140
M2
X
130
M1
M3
149
Y
X

FIG. 34

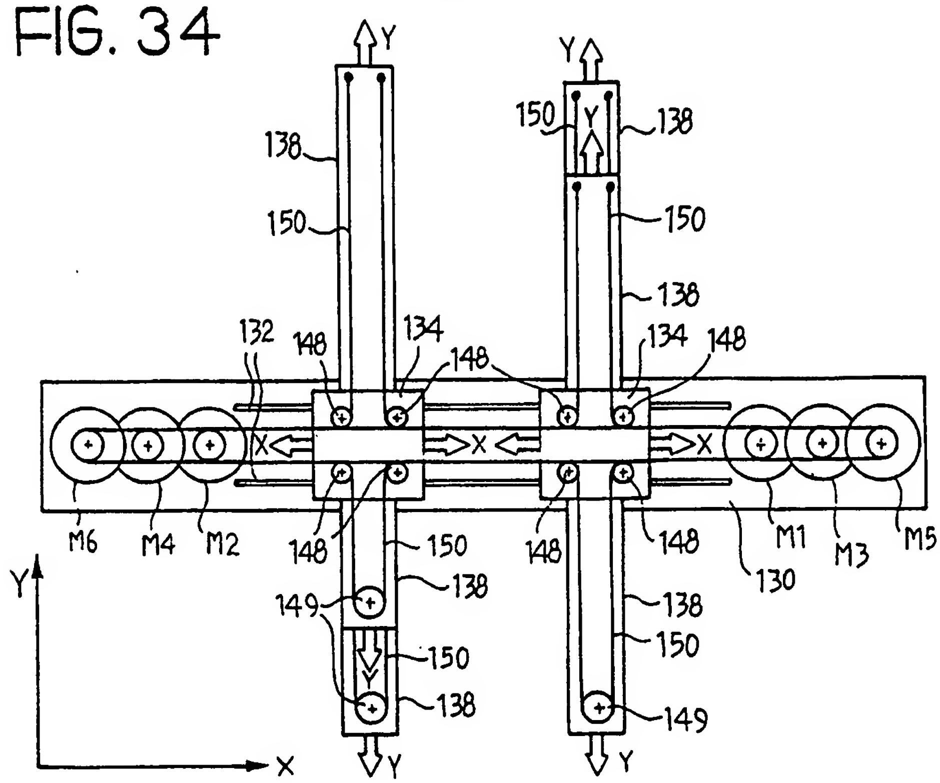
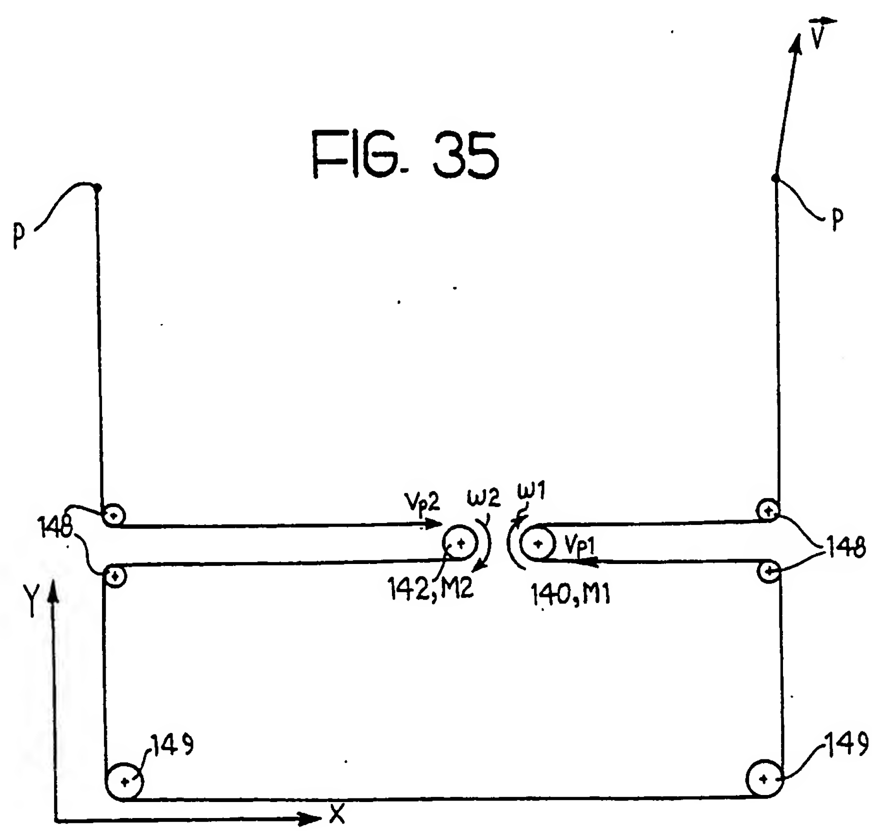

Y
Y
138
150
Y
138
150
138
132
148
134
148
134
148
148
X
X
X
X
M6
M4
M2
148
150
148
148
M1
M3
M5
130
138
149
150
138
138
150
149
Y
Y
Y
X

FIG. 35


V
P
P
Vp2
ω2
ω1
148
Vp1
148
142,M2
140,M1
Y
149
149
X

INTERNATIONAL SEARCH REPORT

Inter 'onal Application No
PC1/EP 96/02202

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B25J9/10 B25J9/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B25J B43L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR,A,2 590 560 (GUILBAUD) 29 May 1987 see page 6, line 34 - page 14, line 35	1,2,5-7
X	FR,A,2 398 937 (ETCHEPARRE) 23 February 1979 see page 3, line 4 - page 4, line 6	1-3,6,8,10
X	DE,U,94 17 837 (BLEICHERT FORDERANLAGEN) 26 January 1995 see claim 1	1,2,4,6
X	US,A,5 063 334 (TANITA) 5 November 1991 see column 3, line 38 - column 9, line 35 see column 22, line 4 - column 24, line 49	1,2,4,6,8

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
20 August 1996	04.09.96

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Lammineur, P

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 96/02202

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US,A,5 265 490 (AZUMA) 30 November 1993 see column 5, line 3 - column 8, line 57	1,2,6,7 9
X	US,A,5 324 163 (COSTA) 28 June 1994 see column 2, line 40 - column 3, line 66	1,2,8
X	DE,A,43 07 151 (BOSCH) 8 September 1994 see column 3, line 39 - column 4, line 39	1,2,6,7
X A	US,A,5 198 736 (AZUMA) 30 March 1993 see column 6, line 28 - column 10, line 20	1,2,6 9
X	GB,A,1 226 936 (KURIBAYASHI) 31 March 1971 see page 2, line 16 - page 3, line 26	1-3,5
X	FR,A,2 676 955 (FAVEYRIAL) 4 December 1992 see page 6, line 8 - page 8, line 18	1,2,10
X	DE,A,39 26 670 (SIEMENS) 14 February 1991 see the whole document	1,2,4
X	DE,A,41 40 687 (WEINERT) 17 June 1993 see claims 1,2	1,2,8
X	EP,A,0 310 481 (EUDE) 5 April 1989 see column 2, line 42 - column 3, line 41	1,2,4
X	US,E,32 414 (HUTCHINS) 12 May 1987 see claim 1	1,2
X	EP,A,0 315 310 (THE KEMBLE INSTRUMENT CO.) 10 May 1989 see column 4, line 15 - column 7, line 17	1,2,4,5

1

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Intr ional Application No

PCT/EP 96/02202

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
FR-A-2590560	29-05-87	NONE		
FR-A-2398937	23-02-79	CA-A-	1108436	08-09-81
		DE-A-	2832095	15-02-79
		GB-A,B	2002910	28-02-79
		JP-A-	54064256	23-05-79
		US-A-	4315437	16-02-82
DE-U-9417837	26-01-95	NONE		
US-A-5063334	05-11-91	JP-A-	3055137	08-03-91
		JP-A-	3055177	08-03-91
		JP-B-	7080142	30-08-95
		JP-A-	3055178	08-03-91
		JP-A-	3117578	20-05-91
US-A-5265490	30-11-93	JP-A-	4294985	19-10-92
US-A-5324163	28-06-94	US-A-	5476358	19-12-95
		US-A-	5533858	09-07-96
DE-A-4307151	08-09-94	NONE		
US-A-5198736	30-03-93	JP-A-	4360787	14-12-92
		JP-A-	5104462	27-04-93
		JP-A-	4183580	30-06-92
GB-A-1226936	31-03-71	NONE		
FR-A-2676955	04-12-92	NONE		
DE-A-3926670	14-02-91	NONE		
DE-A-4140687	17-06-93	DE-U-	9115369	26-03-92
EP-A-310481	05-04-89	FR-A-	2621271	07-04-89
		DE-A-	3878621	01-04-93
US-E-32414	12-05-87	US-A-	4507044	26-03-85
		CA-A-	1213631	04-11-86

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 96/02202

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-E-32414		DE-T-	3249275	03-05-84
		EP-A-	0095500	07-12-83
		GB-A,B	2123790	08-02-84
		WO-A-	8302106	23-06-83
EP-A-315310	10-05-89	GB-A-	2210350	07-06-89
		DE-D-	3887269	03-03-94
		DE-T-	3887269	25-08-94
		JP-A-	1183382	21-07-89
		US-A-	4922173	01-05-90

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